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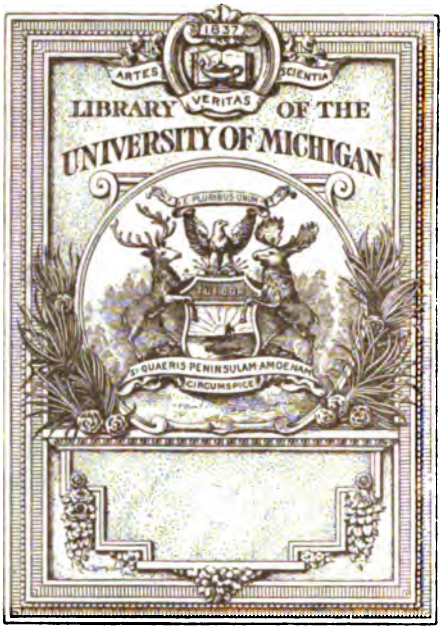

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GEOLOGICAL SURVEY OF CANADA

REPORTS AND MAPS

OF

INVESTIGATIONS AND SURVEYS

3

xiv—A

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GEOLOGICAL SURVEY OF CANADA

ROBERT BELL, M.D., Sc.D. (CANTAB.), LL.D., F.R.S.

ANNUAL REPORT

(NEW SERIES)

VOLUME XIV

REPORTS A, B, F, H, J, M, O, S.

1901

OTTAWA
PRINTED BY S. E. DAWSON, PRINTER TO THE KING'S
MOST EXCELLENT MAJESTY
1905

No. 907

To the Honourable
Frank Oliver, M.P.,
Minister of the Interior.

Sir,—I have the honour to submit Volume XIV (New Series) of the Report of the Geological Survey of Canada.

It is accompanied by 25 maps and is illustrated by several photographs, besides a number of figures in the text.

The several parts composing the volume have been issued previously, as completed, and may be obtained separately.

I have the honour to be, Sir,
Your obedient servant,

ROBERT BELL
Acting Director.

Ottawa, 16th October, 1905.

151838

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GEOLOGICAL SURVEY OF CANADA
ROBERT BELL, M.D., D.Sc., LL.D., F.R.S.

SUMMARY REPORT

ON THE

OPERATIONS OF THE GEOLOGICAL SURVEY

FOR THE YEAR 1901

BY

THE DIRECTOR

OTTAWA
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SUMMARY REPORT

ON THE

OPERATIONS OF THE GEOLOGICAL SURVEY

FOR THE YEAR 1901.

OTTAWA, January 1, 1902.

The Honourable **CLIFFORD SIFTON**, M.P.,
Minister of the Interior.

SIR,—Having requested me to take charge of the Geological Survey Department immediately after the lamented death of Dr. G. M. Dawson, which took place on March 2, 1901, it now becomes my duty under the Act governing the department, to report to you on al matters connected with its administration during the calendar year just closed. I have, accordingly, the honour to submit the following Summary Report on the affairs of the Survey for the above period. This report, besides being what may be termed a short business statement of the work performed by the Survey during the year, contains, in the various subordinate reports, of which it is partly composed, an epitome of the principal scientific results which have been achieved. It embraces the statements of the various officers who were entrusted with the field operations, and also of the gentlemen engaged in carrying on and supervising the several divisions of the indoor work. Nature of report.

Care has been taken to give prominence to any discoveries which may have an economic bearing. This is done in response to the general desire for early information on all points which may be of immediate value to the public, although the scientific discoveries may ultimately prove of greater practical importance. For the above reason some of the accompanying reports on field-work are fuller than usual, although the work they represent may not have been any greater than where the reports are shorter. In the latter case the results will be given at greater length in the detailed annual reports, which are to follow as soon as the field notes can be worked up, and the maps or other illustrations can be prepared. Of such reports, volume XI., containing nine individual sections of this character, with maps, etc., has been pub- Economics.

lished (in cloth covers) during the past summer. Some of these constituent parts had been already issued as "separates."

Published in 1901.

The following are the publications of the department in 1901 :—

Summary report of the Geological Survey for 1900, pp. 203, part A., vol. XIII.

Report on the Topography and Geology of Great Bear Lake and of a chain of lakes and streams, thence to Great Slave Lake, by J. Mackintosh Bell. Part C., vol. XII., pp. 36.

Report on the Atlin Mining District, by T. C. Gwillim. Part B., vol. XII.

Report on the Iron Ore Deposits along the Kingston and Pembroke Railway in Eastern Ontario, by E. D. Ingall. Part I., vol. XII., pp. 91.

Report of the section of Chemistry and Mineralogy, by G. C. Hoffmann. Part R., vol. XII., pp. 64.

Section of Mineral Statistics and Mines, Annual Report for 1899, by E. D. Ingall. Part S., vol. XII., pp. 144.

Report on the Geology of Argenteuil, Ottawa and part of Pontiac Counties, Province of Quebec and of portions of Carleton, Russell and Prescott Counties, Province of Ontario, by R. W. Ells. Part J., vol. XII., pp. 138.

Report on the Geology and Natural Resources of the area included in the map of the City of Ottawa and vicinity, by R. W. Ells. Part G., vol. XII., pp. 77.

Annual Report, vol. XI., new series, 1898, English edition, pp. 853.

Annual Report (new series), vol. X., French edition, pp. 1,117.

Special Reports published in 1901.

Altitudes in the Dominion of Canada, by James White, pp. 266.

Catalogue of the Marine Invertebrata of Eastern Canada, by J. F. Whiteaves, pp. 271.

The maps, sections, profiles, diagrams, etc., published by the Survey during the year are enumerated in the accompanying report by the geographer and chief draftsman of the Department.

FIELD WORK.

The great feature of the operations of the department for the year is, of course, the amount of field-work done, as most of the other proceedings of the Survey depend upon this. During the past summer 31 parties were out, as against 13 employed the previous season, and the amount of work accomplished is believed to have far exceeded that of any previous year in the history of the department. The average number of field-parties for the last ten years has been 14 or 15. Besides sending out all the men qualified for field-work belonging to the regular staff, a sort of contract system was adopted, by which the temporary services were secured of a number of competent geologists, principally college professors, who could only devote the summer season to this work. A lump sum was paid for the field-work, together with all maps and reports thereon. While this plan happened to suit these gentlemen, it was also a very economical and advantageous one for the department, since a large amount of field-work was secured at much less cost than by employing officers for the entire year. Under this system, the gentlemen so employed in the field agreed to plot their work and write their reports at their own homes, thus relieving, without cost for rent, heating, &c., our congested offices at head-quarters. They send in their map-work from time to time at different stages in its progress for inspection by the Geographer of the Department.

31 parties in field.

Contracts.

Advantages.

All the gentlemen who were employed in field-work have given in reports on their labours, and statements covering the year's operations have also been furnished by the Chemist and Mineralogist, the Mining Engineer, the Geographer, the Palæontologist and Zoologist (and his two assistants), the Botanist and Naturalist (and his assistant), the (Honorary) Entomologist and the Librarian.

In former years the Summary Reports of most of the officers of the department were run together under the name of the Director, but in the present volume a distinct heading as to subject is given to the report of each member of the staff and it is published under his own name. In this way the reader may more readily find what he is looking for, and each writer will be more likely to receive the credit due him for his own work.

Individual reports.

As all the more important points in connection with the various operations of the Survey during the year 1901 are set forth in the individual reports, which explain themselves, it will be unnecessary for me to give more than the following convenient summary of the field-work accomplished, the order being from north-west to south-east.

Field officers and their work.

Field officers and their work—*Cont.*

Mr. R. G. McConnell, assisted by Mr. Joseph Keele, worked in the Yukon district. Mr. McConnell's investigations were connected with the mode of occurrence of gold, both alluvial and in veins, and the investigation of new districts as well as those which he had visited in previous years. Mr. Keele was engaged during part of the time on an investigation of the copper deposits of the White Horse district, which were also visited by Mr. McConnell.

Mr. R. W. Brock continued his investigations in British Columbia, in the Boundary Creek district, in West Kootenay, particularly in the neighbourhood of Greenwood and on the north fork of the Kettle river. In addition to tracing out the geographical distribution of the formations, he paid particular attention to the nature of the rocks themselves and to their relations to the ore deposits, and he has written a pretty full report on these subjects.

Dr. Reginald Daly, formerly Instructor in Geographic Geology in Harvard University, became connected with the Survey in May, 1901, and during the past season was employed on the western part of the International Boundary, from the Pacific ocean eastward into the first range of mountains.

Mr. J. M. Macoun acted as Botanist and Zoologist to the Canadian Commission in connection with marking the same boundary.

Mr. W. W. Leach, assisted by Mr. T. Denis, of the Survey staff, was employed in the Crow's Nest Pass coal-fields, in continuation of the work heretofore performed by Mr. James McEvoy, who has left the Service and become connected with a coal mining company operating in the Crow's Nest Pass region. The result of the investigations of Mr. Leach and Mr. McEvoy is to show that there is an enormous aggregate thickness of coal in the main basin in the neighbourhood of Fernie, divided amongst a great number of seams of convenient thickness for working. He also investigated the southern part of the Green Hills coal-fields, lying about thirty miles north of the main field. Here also there is a vast amount of workable coal, which, like that of the main field, is of excellent quality.

Mr. Lawrence Lambe, one of the assistant palæontologists of the Survey, was engaged with a party collecting fossils on the Red Deer river, to the north of Medicine Hat. He brought home a fine collection of the remains of Upper Cretaceous reptiles, and since his return has described two species of tortoises, these descriptions, with illustrations, being included in his report.

Field officers and their work—*Cont.*

Mr. William McInnes continued his surveys between Lakes Superior and Manitoba, in which region he has now mapped out all the more important Huronian belts and described the characters and structure of the rocks which they comprise.

Mr. D. B. Dowling, assisted by Mr. W. H. Boyd, of the Survey, was sent to the country lying to the south-west of Cape Henrietta Maria, on the western side of Hudson Bay. The limits of the different formations within this district had never before been mapped out. The great region lying on this side of the bay is of a generally low and level nature, but behind Cape Henrietta Maria a hilly country was known to exist. On the older geological maps this was represented as Laurentian, but I had predicted that it would more likely turn out to be of Lower Cambrian age and to consist of rocks like those of the Manitonnuck formation on the east side of Hudson bay, which is equivalent to the Animikie of Lake Superior. This prediction was fully confirmed by Mr. Dowling's investigations. The party surveyed the west coast of James bay from Moose Factory north to the above mentioned cape, and they also made an instrumental traverse of the Equan river and a track-survey thence northward by way of Sutton Mill lake to the main bay.

Dr. Alfred W. G. Wilson made a detailed geological survey of the country lying immediately west of Nipigon river and lake, at the same time mapping out all the geographical features which had not been laid down by myself when surveying the lake in 1869.

Dr. W. A. Parks, assistant professor of geology in the University of Toronto, was employed during the summer vacation in making a topographical and geological survey in the country lying to the eastward of Nipigon lake and river. It is expected that the work of these two gentlemen when combined with my own in one sheet, will give a very accurate representation of both the geology and topography of this whole region.

Mr. W. J. Wilson, of the regular staff, assisted by Mr. Thomas Davies, was engaged in defining more accurately the boundaries between the Laurentian and Huronian rocks in the region lying around and to the westward of Abitibi lake and river. His work is shown upon the accompanying preliminary map.

Mr. Frank Johnson did similar work in the country to the east and south-east of the same lake, and his results are also indicated on this map. In both cases topographical surveys were made simultaneously with the geological examinations, and a complete geological map of the whole of the Abitibi country is now being constructed.

Field officers and their work—*Cont.*

The writer spent part of the summer and autumn in geological researches from Kippewa lake to Grand lake and in the region to the northward of the latter, in continuation of surveys and explorations which he had made in that district in previous years. These researches showed the existence of several alternating belts of Huronian and gneissic or granitic rocks.

Dr. Alfred E. Barlow was engaged in the Sudbury nickel and copper district in tracing in greater detail some of the rock-formations in the same area which he had assisted me to investigate in 1887-90 and which are represented on the geological map, published with my report on the district in 1890. One of Dr. Barlow's principal objects was to ascertain whether or not the relative richness in nickel of the pyrrhotite ores was in any way related to the composition or other characters of the different eruptive country-rocks in which they occur.

Prof. Frank D. Adams continued his investigations in the Haliburton district, lying to the north-east of Toronto, where he and Dr. Barlow have now completed a geological survey of a large area of highly interesting rocks belonging mostly to the Upper Laurentian system.

Mr. L. N. Richard was in the field a portion of the season, making some topographical surveys in the western part of the area covered by the Bancroft map, which were required by Dr. Adams in order to enable him to lay down accurately his geological lines in that part of the sheet.

Prof. John Macoun, botanist and naturalist to the Geological Survey, while pursuing investigations in his own Division around the north shore of Lake Erie and the east shore of Lake Huron, also made additions to our knowledge of the surface geology of these regions. He made a special investigation as to the fruit-growing capabilities of the districts examined.

Dr. Robert Chalmers carried out during the summer an extensive reconnaissance survey of the superficial deposits of the interlake peninsula of Ontario, together with some investigations into the results of boring for petroleum, gas, salt and water within the same region. Previous to Dr. Chalmers' work the superficial geology of this region had been more or less investigated for the Survey by myself in the early sixties and later by Dr. J. W. Spencer, Mr. F. B. Taylor, Prof. Gilbert, and others, as amateurs.*

---

* Dr. Chalmers' investigations included the country around London, Ontario. After his return in the autumn he was requested by the city engineer and water commissioners of that city to return and give them the benefit of his opinion as to the best means of securing a large and reliable supply of good water. He acceded to this invitation and his advice will, no doubt, prove of value.

Field officers and their work—*Cont.*

Dr. Henry M. Ami was instructed to perform in the province of Quebec, westward of the city of the same name, and in part of the Ottawa valley, work similar to that assigned to Dr. Chalmers in Ontario.

Mr. E. D. Ingall, mining engineer to the Survey, in addition to his usual duties in connection with mines and mineral statistics, completed his report on the iron ores of Eastern Ontario and Western Quebec, and it has lately been printed for the department. He also visited some of the iron mines in these districts.

Dr. R. W. Ells was again engaged in a geological survey of the district around Kingston and thence east and west, and has collected sufficient data to map out the boundaries of the various palæozoic formations in that part of the country.

Principal J. A. Dresser, of St. Francis College, Richmond, P.Q., was engaged during his vacation in making a petrographic study of Brome mountain, east of Montreal. In previous summers Principal Dresser had made similar studies of some of the other isolated intrusive masses in the province of Quebec, and these, together with the studies of Mr. LeRoy and Professors Harrington and Adams, complete our knowledge of the lithological character of all the isolated mountains in the remarkable chain extending from Rigaud on the west to Brome on the east.

Prof. A. Osann, of Mülhausen, Germany, has completed a highly interesting report on his petrographic studies, both in the field and laboratory, in regard to a variety of crystalline rocks occurring east, west and north of Ottawa city. This report, which is well illustrated, is now in press.

Prof. Laflamme, of Laval University, carried out a further geological examination of the Island of Anticosti, in the mouth of the St. Lawrence, on behalf of the Geological Survey. In doing this he has added considerably to our general and geological knowledge of this large island, and has brought home a collection of the fine fossils which occur there in the Middle Silurian rocks.

Prof. L. W. Bailey, of the University of New Brunswick, made further researches, on behalf of the Survey, into the geology of southern New Brunswick, and also did some work on the Carboniferous of the northern part of the province.

Prof. H. S. Poole, of Dalhousie University, Halifax, was requested to investigate the whole coal problem in New Brunswick, with a special view to determining whether or not workable coal seams might

Field officers and their work—*Cont.*

be found by boring in any part of the wide distribution of the Carboniferous rocks in the north-eastern part of the province. In performing this work Mr. Poole was assisted for a part of the time by Dr. L. W. Bailey.

Mr. Lawrence W. Watson, of Charlottetown, P.E.I., undertook certain scientific researches in the Province of Prince Edward Island, in which but little official geological work had heretofore been done. The results of Mr. Watson's investigations promise to lead to interesting results in some of the lines he took up.

Dr. George F. Matthew continued field-work in connection with his palæontological studies in Cape Breton. He is preparing a general report (which will be illustrated) as to the palæontological results of several years work in the lower provinces.

Mr. E. R. Faribault, who has made geological surveys of most of the gold mining districts in Nova Scotia, continued his investigations in this direction during the whole season. Mr. Faribault has now been enabled to demonstrate the true history and origin of the gold-bearing veins of these districts.

Mr. C. O. Senécal was engaged part of the season in Nova Scotia in running base lines with a view to connecting the gold district plans prepared by Mr. Faribault, and also to securing accuracy of position as to certain geological work heretofore done by the Survey in Nova Scotia.

Mr. Hugh Fletcher continued the work in Nova Scotia in which he has been engaged during the last thirty years. He has now nearly completed his geological survey of the coal-fields and was more particularly occupied this summer in Cumberland County. Mr. Fletcher has finished ten map-sheets, showing details of the geology, especially in the north-eastern half of Nova Scotia, as the result of his labours during the latter part of the above period. These have been engraved and it is expected they will be published during the present winter.

Mr. C. W. Willimott was in the field all summer, engaged in collecting supplies of minerals and rocks to be used in meeting the demand from educational institutions for specimens for illustration in teaching mineralogy and geology. The collections of good specimens which are sent by the Survey, under certain conditions, to universities, collegiate institutes, academies and schools, all over the Dominion, constitute a very important adjunct in the teaching of mineralogy. Mr. Willimott, who has had much experience in collecting and knows the best localities to go to for the minerals required, worked in the provinces of Ontario, Quebec, New Brunswick and Nova Scotia. He sent in a large supply of good material for the above purpose and also many fine specimens suitable for exhibition in our own museum. The results of his labours are given more fully in Dr. Hoffmann's report. We are indebted to several managers and owners of mines, quarries, &c., for sending us generous quantities of material, thus saving Mr. Willimott the necessity of going himself for it.

Field officers and their work—*Cont.*

Mr. R. L. Broadbent made some trips to the field for the purpose of obtaining mineral specimens required for the museum as well as for the educational collections. His work is also referred to in Dr. Hoffmann's report.

Outside aid.

We are indebted to Mr. Henry O'Sullivan, P.L.S., of Quebec for tracings of his surveys on the southern and eastern shores of James bay; and we expect to receive a good deal of interesting geographical and geological information from several persons not connected with the department who have been travelling in some of the northern parts of the Dominion. Some of the former members of the staff have also kindly promised to contribute their geological observations over wide areas which will always help to fill in the geological map. Among these are Mr. J. B. Tyrrell of Dawson, Mr. A. P. Low and Mr. J. Mackintosh Bell.

Mr. A. P. Low.

Mr. A. P. Low resigned from the Survey early in 1901 in order to accept a position offered him by a syndicate of United States capitalists. He proceeded to the eastern coast of the Hudson bay, in order, amongst other things, to locate mining claims on the extensive manganiferous iron deposits which were discovered by me on the Nastapoka islands, in that region, in 1877 and described in my report of the same year. Before leaving, Mr. Low promised to try to send to the Survey reports and maps showing the geological information which he might incidentally acquire in connection with his present work.

Mr. J. M. Bell.

Mr. J. Mackintosh Bell, who had accompanied me, as assistant, to Great Slave lake in 1899 remained at that lake during the following winter in order to proceed on an exploration of Great Bear lake and the surrounding country the next summer. Returning in the end of 1900, he completed a map and report of his work for the Survey, after which he accepted a position as explorer and geologist, offered by Mr. F. H. Clergue of Sault Ste. Marie. He worked, aided by two assistants whom he detached separately from his own party, between Lake Superior and the east side of James bay. It is expected that Mr. Clergue will ultimately give the Survey the benefit of Mr. Bell's purely geological results in the above region.

Primary object of the Survey.

The primary object for which the Geological Survey was instituted and for which it is being carried on is to aid in the development of the mineral resources of Canada, and the constant aim of those engaged in its work is to carry out this object in the best possible way and by methods approved by intelligent men who have a knowledge of how the end in view can be best attained. This is not by an indiscriminate search for individual "mines" without regard to the nature of the rocks, but by scientific and systematic methods based on knowledge and experience gathered by educated men all over the world.

Distribution of formations.

Among the first things which a geological survey requires to do, is to trace out the geographical distribution of the various rock formations, some of which carry economic minerals, while others do not. It is important to point out where such minerals are not to be found as well as where they may be looked for with success. In the case of metals and their ores, the conditions and modes of occurrence are studied by our field geologists, so that the efforts of the prospector may be properly directed and his attention confined to the most promising parts. A study of the conditions of occurrence of any ore which may be found in a particular formation will enable us to judge intelligently as to the probability of the discovery of such ore in workable quantity or otherwise.

Non-metallic minerals.

In the case of economic minerals of a non-metallic character, such as coal, petroleum, salt, fire-clay, etc., a knowledge of the structure, composition, geological age and other matters in regard to a rock formation may enable the geologist to pronounce upon the probable occurrence of such minerals, their depth from the surface at any given point, or as to any other circumstance in connection with them, with an accuracy which would be impossible to a person who had not this geological knowledge. The information obtained by the joint labours of large numbers of geologists during a long period and in all parts of the world, has been brought together by a free interchange of knowledge in a scientific spirit. It has become the common property of all and may be utilized by anyone who has been trained to understand such subjects. The above two examples of the utility of a geological survey are given, out of many that might be cited. But surely in this enlightened age, it should not be necessary to defend the valne of scientific knowledge and experience in connection with such investigations as are entrusted to the Geological Survey. I wish, however, to call attention to the eminently practical character of all the branches of work carried on by the department.

Practical character of the Survey's work.

As the nature of the various operations of the Survey above referred to, seems to be imperfectly understood by many, a few words of explanation may not be out of place. These operations may be divided into field and home work. The former consists in obtaining original information in various parts of the country, collecting specimens for further examination, etc. This work is done almost entirely in the open season. The elaboration of this information is carried on mostly at headquarters in the winter by the same men, with help from the draughtsmen, chemists, lithologists, palæontologists, or other members of the indoor staff.

Topographical surveying.

Much of our work being prosecuted in unsurveyed and even unexplored territory, topographical surveying becomes a prominent part of our duty. It would, of course, be of little use for our officers to do geological work in previously unexplored districts, if, on their return, they could not represent it in its proper geographical position. Each field man, therefore, requires to be a topographical surveyor, as well as a geologist. It will thus be seen that the qualifications of a field geologist in Canada must be of a much wider and more varied character than would be required in an older country, where the topography is already well represented on the maps. Our geographical work embraces surveying of all kinds, from accurate measurements of base lines to track surveys and mere explorations. It includes triangulation of lakes, sea coasts and mountainous regions, surveys on land by transit and chain, odometer, pacing, etc.; on water by micrometer telescopes, boat logs and time reckoning. Observations for latitude and longitude require to be made at frequent intervals, especially in the more distant regions. Altitudes should be taken everywhere, either by barometer or spirit level. When working on the water, soundings are made as often as possible. Sooner or later all such facts prove valuable, and they can be noted by an energetic man in connection with working out the geology. In order to be able to carry on work in the wild or uninhabited parts of the country, the geologist requires to understand the selecting of suitable men for the work, the equipment and management of a party under varying conditions, far from civilization, methods of travel, of finding food in wild regions, etc. Unforeseen difficulties often arise which require patience, skill and endurance to overcome. The geologist in charge of a party in remote regions must, therefore, be a man of energy, resources and experience.

Various kinds of surveys.

Geologists qualifications.

Geology being the prime object of these surveys and explorations, the man in charge of one of our parties requires, in addition to the topography, to attend constantly to recording a variety of observations as to the nature of the rocks, their distribution, dip or strike, the run of veins, joint and cleavage planes, dykes, etc., glaciation or other surface conditions, the superficial deposits, etc; he requires also to collect and label specimens of rocks, minerals and fossils. Particular attention is directed to the occurrence of useful minerals and rocks of any kind in new districts and to the examination of any discoveries, and to workings by prospectors and miners, with a view to his forming a correct estimate of the outlook for mining or quarrying in such districts.

Useful minerals.

Variety of observations.

While working in new territory we also take advantage of the opportunity to obtain heights of banks or cliffs, hills and mountains and comparative levels of waters, grades and depths of streams and lakes, records of the temperature of the air and water and of other meterological observations as indications of climate, notes as to the kinds and characters of the forest trees and on the flora generally; also as to the fauna, the collection of zoological and botanical specimens, making notes on the nature of the surface of the country, whether hilly or level, rocky, swampy or covered with soil, the character of the land, and on various other matters. We also enquire from the natives as to the topography, etc., of regions beyond our own explorations. Photographs are taken to illustrate the geology, scenery, the character of streams, etc. All these duties being carried on by the same person, in addition to his general management of the party and pushing on of the work, require constant attention and labour and they often involve danger and privation, as well as discomfort from the weather, the plague of mosquitoes and various other insects, and are unaccompanied by any of the comforts and advantages enjoyed in civilized parts.

Work at headquarters.

Among the numerous and varied branches of work prosecuted by the staff at headquarters is map-drawing in all its departments, supervision of map-engraving, the preparation of reports giving the results of the different kinds of work being done, looking after the printing and illustration of these reports, testing, assaying and analysing ores, rocks, coals, clays, sands, waters and mineral substances generally, the business of the Section of mines and mineral statistics, petrographic work, preservation, determination, description and utilization of the fossils collected and the illustration and publication of the results of palæontological research, lapidary work, the preservation, determination and mounting of zoological specimens, studies in connection with the fauna of our vast country, including entomology, the mounting, naming, cataloging, classification and the description of new species and varieties of the plants collected, the study of the economic results of botanic researches in the field, the supplying of good named and catalogued collections of specimens of minerals and rocks to educational institutions of various grades, from elementary schools to universities, after we have collected these from widely separated parts of the Dominion, work connected with the archæological collections, with the accountants' branch, with the care and increase of the library, the sale and distribution of the maps, reports and other publications of the Survey, the care of the different departments of the museum, the varied duties of the secretary, photographic work, attending to daily personal enquiries on a great range of subjects, and the correspondence connected with every branch of the service.

Subject of correspondence.

The correspondence of the office covers a wide range of topics of the most varied character, embracing enquiries on almost every subject connected with geology, geography, mapping, rocks, ores, minerals and materials of all sorts, mines, mining, markets and statistics of mineral products, chemistry, metallurgical questions, forests and timber, flora, fruit-culture, fauna, protection of game and fish, hunting, fishing and travelling in wild parts of the country, engineering, surveying, exploring, characters of wild and settled regions, sub-division of land, health resorts, information for proposed visitors and immigrants, climate, mineral statistics, the naming of specimens and of whole collections, questions in geology, palæontology, biology and nearly all the natural sciences, as to aboriginies, surveys and instruments, values and uses of economic minerals, as to text-books, requests for information on a great variety of scientific subjects. Many of the letters refer to matters altogether foreign to any branch of our work. One of the more numerous classes of letters is that asking for our reports, maps and other publications, which now number 657 titles, of which 607 are enumerated in the last List of Publications of the Survey, which is sent free to applicants. A nominal charge is made for these publications to prevent an indiscriminate demand from persons having no real need of them. The above example will serve to illustrate the main features of the correspondence carried on. The letters and enquiries received relate to almost every scientific subject except electricity. Some of the demands are far-reaching and elaborate, and require voluminous answers, the preparation of which consumes the time of the higher officers of the Survey. In fact, the department seems to be considered a bureau of free information on all subjects such as those which have been mentioned. All letters are answered promptly; and we are frequently thanked by the correspondents for the pains we have taken to satisfy them.

Good results.

The supplying of all this information, both by letter and to personal applicants, as well as the numerous other services rendered in the various ways above indicated, must be of great assistance to the applicants, and it constitutes an important means of promoting the progress of the country. Having the necessary information on the above subjects, together with the extensive personal knowledge of the remoter parts of the Dominion, possessed by various members of the staff enables the Survey to give valuable and reliable information to inquirers both at home and abroad on almost any subject relating to Canada.

MAPS.

The value of accurate maps in connection with the delineation of geological formations was fully appreciated by the late William Logan from the beginning of the Survey and was dwelt upon by him in the earlier reports. He collected assiduously all charts and maps, whether printed or in manuscript, relating to Canada and secured any desirable collections which could be obtained by purchase. In this way large numbers of maps were acquired from surveyors and others which it would be impossible to obtain at the present day. Copies were made of all serviceable maps and plans in the Crown Lands Offices of both Upper and Lower Canada and the surveys which were carried on for geological purposes were often the means of making important corrections in these.

Maps collected.

Later on in the progress of the country, when explorations and surveys were being made for railways, boundary lines, lumbering operations and other purposes, tracings of the resulting maps and plans were secured as soon as possible. It was in this way that copies of a large proportion of the plans of the government survey of the Canadian Pacific Railway were preserved at the time the offices of this survey were burnt and the originals destroyed at Ottawa in 1872.

Plans preserved.

But above all, the extensive surveys and explorations which have been made by the geological staff itself, year after year, throughout the comparatively long period during which its operations have been carried on, have been the means of mapping out the principal part of what is known of the topography of Canada. The maps, plans and charts in our collection, not counting those of small areas, now number about 20,000. It is safe to say this is the largest and most valuable collection of such documents in the Dominion, and it constitutes the most precious part of the property of the department. The Survey is now in the sixtieth year of its existence and the necessary topographical surveys, incidental to the geological investigations, are being prosecuted more vigorously than ever and over a much wider range than in the earlier years, when only two provinces claimed attention, instead of half a continent.

Topography of Canada.

It may be said that the Geological Survey is the only distinctly topographical branch of the public service and that the large number of maps which it has produced from time to time have always been recognized as the most accurate obtainable in regard to topography, to say nothing of their primary object—the geology which they represent. Our published maps already number about 350, while considerable additions are in various stages of preparation, and we have on hand the data for the construction of many more. The cost of producing these maps, from the original survey by the officers of the staff, the drafting, compiling, etc., up to the finished engraving, has been extremely small in comparison with their utility and value to the country. An immense amount of work has still to be done before the remainder of even the habitable parts of the Dominion are mapped out, but with the increased facilities now at the disposal of the department, this work can be prosecuted even more rapidly and economically than before.

Accuracy of maps.

Small cost.

The process of carrying on a geological survey of such a vast, and for the most part, unsurveyed country as Canada, must necessarily be entirely different from the methods employed in well surveyed and comparatively small countries. The geology of Canada has been already outlined with more or less completeness in the older parts of the country, that is, in regions where the lands have been divided up and settled, although even here, much remains to be done in some districts, but in the greater part of the area of the Dominion the need of surveys for other than geological purposes has not been sufficiently pressing to justify the great expenditure which would be required to make topographical or cadastral surveys far in advance of immediate requirements.

Methods differ.

It has, therefore, remained for the Geological Survey to do its topographical work simultaneously with the geological, and thus the country has had the benefit of both at a remarkably small cost. The Survey has thus been a most useful institution for the general progress of the country, and as no better method could be employed, the same topographical system must continue if we are to have the whole country mapped out at all, and as the geological work adds little or nothing to the cost, we might as well have it done at the same time.

Simultaneous work.

The long experience of sixty years which the Survey has had in carrying on these combined surveys in all parts of British North America, from Nova Scotia to the Yukon and Lower McKenzie, and from Vancouver Island to Baffinland, has developed a very efficient system for the execution of this work, both as regards accuracy and rapidity on the one hand, and economy of expenditure on the other.

Sixty years' experience.

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The methods pursued, and the results obtained, have always met with the highest approval from all impartial persons capable of judging.

Whether the particular survey to be made be one requiring instrumental accuracy, or one of those carried on by rougher methods in previously unexplored regions, where long distances or large areas are covered in a short time, the officer in charge of the party and his professional assistant work together at both the topography and the geology. Map-making. On returning to winter headquarters, the plotting and preliminary work on the map are done, mostly by the assistant, but partly by both, with perhaps the assistance of a draughtsman, and the compilation of the map, on the scale adopted for publication, is proceeded with and carried to completion under the supervision of both the geographer and the geologist or his assistant. When the compilation is sufficiently advanced, the geologist writes his report, which he could not do without the map. All the geologists being engaged in a similar way, a number of valuable original maps, combining topography and geology, are wholly or partly constructed every winter, and the field geologists and their assistants are ready to go back again to the outdoor work as soon as the season comes round. During summer, when the geologists are away in the field, the geographer and his assistants, being relieved of much of the work of compilation, can devote more time to the drawing for the engraver of such maps as have been completed, correcting proofs of new maps, and otherwise facilitating their final production.

United work necessary.

It will thus be seen that the topographical and geological map-work must necessarily be done in the same office. The geologist must confer constantly with his assistant and both with the geographer and chief draughtsman in order to produce the best possible map from the materials obtained in the field, and he must lay down the geology at the same time as the topography. The presence of a number of geologists and topographers under the same roof is mutually beneficial and promotes an *esprit de corps*. The men take a pride and an interest in their work, and they regard the professional credit which it may bring them, if well done, as of more importance than the pecuniary remuneration they receive.

Control of map-work.

Under the existing system, which was inaugurated nearly sixty years ago by the late Sir William Logan, the department has, so far, secured the services of a superior class of scientific men, who would not give up their time and talents unless they obtained full credit for all branches of this work. Geological surveys in all countries control the issue of their own maps. The mapping of the topographical and geological work of the gentlemen only temporarily connected with the department, which has been already referred to, could only be done under the immediate control of the Survey, and it works in well with our organization, which includes a number of skilled draughtsmen who do no field-work themselves.

A system of map-making, differing from the above, was tried for a time with less success in the Geological Survey office. It consisted in attempting to construct the map from the field data, independent of the geologists and assistants who had done the field-work. But this method has been abandoned as unsuited to our requirements. The present system, which is conservative of both time and energy, has been evolved in all its details after a very long experience in the various branches of the work, and it has proved to be the best that can be followed.

Unsuitable system abandoned.

The department aims at the systematic division and arrangement of the work. The geologist must have constant access to all maps which may refer to the region he is working upon. Our maps, being constructed from surveys under our own control, with the addition sometimes of other reliable data, are always up-to-date and contain the newest and most accurate information. These maps, together with the Summary and Annual reports, are given to the public at the earliest possible moment, but a certain amount of time is, of course, required for the drawing and engraving of good maps. From the fact that they show both the geology and the topography as accurately as they are known, our maps have come to be regarded as the best guides for travellers and prospectors, especially in new regions, and they constitute a distinct advance in the proper mapping of the country.

Early issue of geological maps.

Since the department requires to construct the best possible maps in order to lay down its geological work on various scales, and as it already possesses the largest and richest collection of maps extant, referring to all parts of the Dominion, and which have been obtained largely by its own labours, its base-maps of the whole country or of any portion thereof, on such scales as may be required, could be utilized both on account of their accuracy and for the sake of economy, as well as to save duplication, in the future production of reliable maps for the special purposes of any of the other Departments.

Other uses.

The first large general geological map of Canada was published in 1866. In order to show the relations of the geological formations of Canada to those of the United States, it includes a large part of that country and extends from Newfoundland westward to the Qu'Appelle river, in what is now the province of Manitoba. It is on a scale of 25 miles to an inch and is very finely engraved on steel. The next

General geological maps.

general map issued, shows, in a less detailed manner, the geology of the Dominion from the Atlantic to the Pacific, but it extends north only to Newfoundland in the east and Great Slave lake in the west. It is on a scale of 43 miles to an inch and was producd by lithography.

New geological map of the Dominion.

A map on a scale of 50 miles to an inch, to show the geology of the Dominion, as far as known up to 1902, is now in the engraver's hands, and it is expected that the western half of it will be ready for distribution the present winter. It is done on stone and shows the country as far north as Hudson Strait on the east and Great Bear lake on the west.

ANALYSES, ASSAYS AND EXAMINATIONS OF MINERALS.

Chemical laboratory work.

The report of the Chief Chemist and Mineralogist for the year just closed, in regard to the work of his Division, shows the great importance of this branch of the Survey. Dr. Hoffmann and his two assistants have been engaged principally in the examination, assay or analysis of the specimens received from the field geologists. Some of these were of geological and some of economic interest. They embraced mineral fuels of all kinds, ores of iron, copper, lead, nickel, silver, gold and other metals, mineral waters, rocks required for various purposes, graphite, clays, marls, shales, sands, ochres, etc., and of many of the rarer species of minerals. But in addition to this work, these gentlemen examined during the year 705 samples of minerals which were brought by visitors to the museum or sent by express or through the mails by miners, prospectors, explorers and others from all parts of the Dominion for identification or information regarding them. Dr. Hoffinann furnished a written report on most of these examinations or analyses. During the past twelve years the numbers of specimens thus examined, identified, described or reported upon, as given in the Summary Reports were as follow :

Samples sent and analysed, etc.

Year.	Specimens.
1890	558
1891	705
1892	697
1893	463
1894	694
1895	573
1896	697
1897	985
1898	861
1899	1,017
1900	663
1901	705

For 12 years, 8,618, or at the average rate of 718 a year. The rules of the department require that the locality of occurrence of all specimens be given before they can be examined or analysed in the laboratory.

Minerals inquired about.

The minerals for which information was sought during the year, either by personal application or by correspondence, included the following:—

Albertite, asbestus, barytes, borax, cement, clays, celestite, chromic iron, coal, copper ores, corundum, fire clay, fuller's earth, gas (natural), gold, graphite, granite, gypsum, infusorial earth, iron ores, kaolin, lepidolite, limestone, magnesite, manganese, marble, marl (shell), mica, mineral waters, molybdenite, nickel, ochres, peat, platinum, pyrite, salt, selenite, silver, soapstone, sulphur, talc, tugsten, zinc ores.

Service thus rendered.

In connection with these inquiries, the Survey has been the means of putting parties requiring these minerals, etc., in communication with the producers or owners of properties where they occur, thus promoting the development of various resources and increasing the business of the country.

Value of minera output.

The value of the mineral output of the Dominion is increasing very rapidly. In 1900 it amounted to $64,448,037, while in 1886 it scarcely exceeded $10,000,000. The figures for 1901 are not yet available, but there has been a further increase under most heads, and the working of mines and utilization of the various mineral resources of the country are rapidly taking a foremost place in the great industries of Canada.

COAL-BEARING LANDS OF THE CROW'S NEST PASS REGION.

Coal lands of Crow's Nest Pass.

According to the provisions of Chapter 5, 60 and 61 Victoria, 1897, the Director of the Geological Survey is required to state in writing his opinion as to what are coal-bearing lands within the areas which were granted by the government of British Columbia to the British Columbia Southern Railway Company, its successors and assigns for ever, as subsidy earned by the Canadian Pacific Railway Company under an agreement with the former company and the Dominion of Canada in the construction of the Crow's Nest Pass Railway. On the 15th of October I was requested by the Minister of the Interior to report, according to the requirements of the above mentioned Act, and my return, illustrated by a geological map, was furnished on the 17th of the month.

Surveys of coal field.

In 1900, by direction of the government, a topographical survey of he region was made by Mr. H. O. Wheeler, and a geological survey of it was also made the same year by Mr. James McEvoy, assisted by Mr. Joseph Keele. The latter survey was continued in 1901 by Mr. W. W. Leach, assisted by Mr. T. Denis, and by the month of October we were able to define the coal-bearing lands with sufficient accuracy. These lands consist of two separate areas, the more southern and larger ne containing about 230 square miles, or 147,200 acres, and the maller one, which lies in the Green Hills, at a distance of nearly 30 iles north of the other, containing about 6·75 square miles, or 4,320 cres. There had been rumours of the occurrence of coal elsewhere within the lands belonging to the Canadian Pacific Railway Company, but on investigation by Mr. Leach these were not confirmed.

Immense quantities of coal.

Mr. McEvoy reported that in a total section of 4,736 feet, at right angles to the strata, which he measured in the main, or Crow's Nest Pass Coal Field, there are no fewer than twenty-two seams of coal, with the enormous aggregate thickness of 216 feet, of which, at least, 100 feet may be considered as workable coal. This section was measured at Morrissey siding, and it is all above the level of Elk river. The Canadian Pacific Railway Company has had two borings made near their track, south-east of Michel station. The logs of these borings have been kindly furnished to this department. They both show the existence of numerous seams of coal, and these have been correlated, by Mr. Leach, with those of the section measured by Mr. McEvoy at Morrissey siding. Their relations to one another are described in Mr. Leach's report in this volume and illustrated by the sections which accompany it.

Green hills coal-field.

In the portion of the Green Hills coal-field within the railway company's grant, Messrs. Leach and Denis measured a section of coal-bearing strata of 3,387 feet, containing twelve seams of coal, having a total thickness of eighty-nine feet. Seven of these seams are of workable size, with an aggregate thickness of seventy-nine feet. The section is not complete, as the rocks are covered up or concealed in many places, leaving room for the occurrence of more seams of coal. The sections in Mr. Leach's report, drawn to a scale, show the position, thickness, etc., of each seam in both of the above coal-fields.

GEOLOGICAL MAPS OF NOVA SCOTIA.

Geological maps of Nova Scotia.

The publication of ten geological map-sheets of the north-eastern portion of the mainland of Nova Scotia, prepared in great detail by Mr. Hugh Fletcher of this department, from his painstaking topographical and geological surveys, extending through a period of more than twenty years, was suspended, owing to a difference of opinion, which had been held by some, as to the age of certain geological formations of that part of the province. As Mr. Fletcher's conclusions on this subject have not changed since the publication by the Survey of his previous geological maps in accordance with these views, and as he has given his unremitting study and labour to the correct elucidation and representation of the geology of the region in question, having no object but the truth to maintain, it is not considered desirable to longer withhold from the public these valuable maps, and they will accordingly be published as rapidly as possible. They are already engraved and the colour-stones are being prepared, so that it is expected the printing can be done during the present winter.

MINERALS OF CANADA AT INDUSTRIAL EXHIBITIONS.

Canadian minerals at exhibitions.

Through the efforts of the Geological Survey, the minerals of Canada have been well represented at all the international industrial exhibitions which have been held, from that of 1855 in London to those of last year. These collections and the descriptive catalogues prepared by the Survey to accompany them, have never been excelled by those of any other country. The fine collection which had been got together under the control of the Survey for the Paris exhibition of 1900 was transferred entirely to that held in Glasgow in 1901, and in both cities it served to make known, in a striking manner, the great mineral wealth of Canada.

Zoological specimens exhibited.

At the request of Mr. Wm. Hutchison, the Canadian Commissioner to the Pan-American Exhibition, held in Buffalo last year, the department loaned some zoological specimens, including a fine wood buffalo. These specimens were the means of attracting much attention to the country, and, owing to Mr. Hutchison's careful management, they have been safely returned to the museum.

The collections which were at the Paris and Glasgow exhibitions, are to be shown during the winter in London, and in spring are to be divided between the exhibitions to be held in Cork and Wolverhampton respectively.

ZOOLOGY, BOTANY, PALÆONTOLOGY, ETHNOLOGY, ETC.

Other scientific work.

Dr. Whiteaves' catalogue of the Marine Invertebrata of Eastern Canada, published during the year, is the result of the studies of an

Scientific works.

expert for many years and is a very important contribution to zoological literature. Other work which he has accomplished last year is mentioned in his own report. It will be seen by this report that a considerable number of zoological specimens have been added to the museum. Professor Macoun's botanical work in Ontario, which is described in his report, shows that he made very large collections of plants and a variety of interesting zoological observations in the southern part of the province. He is now engaged in preparing for the press the second part of his *Birds of Canada.* Mr. James Macoun and his assistant did good work with the International Boundary Commission in collecting botanical and zoological specimens and in working out the natural history of the south-west corner of the Dominion bordering on the Pacific ocean. Mr. Lawrence W. Watson has been working on the botany and zoology of Prince Edward Island and has sent some interesting specimens to the museum.

In addition to the palæontological work performed by our own staff, we are greatly indebted to Professor Samuel H. Scudder, of Harvard University, for another valuable voluntary contribution to Canadian palæontology, being part 2 of vol. II. of his *Canadian Fossil Insects,* containing 92 pages and 10 plates, published by the Survey during the year. The figures were drawn by Dr. A. D. Hopkins, of Morgantown, West Virginia. Professor Penhallow, of McGill University, has written and illustrated a report on Osmundites from Queen Charlotte island, which will be published as soon as possible. Several additions have been made to the archæological and ethnological collections, among the latter being a carved totem pole about 40 feet high, obtained for the Department in British Columbia by Dr. C. F. Newcombe. This and four other totem poles from the Pacific coast, which we had on hand, have been erected in the court-yard of the museum.

Totem poles.

VOYAGEUR WHO WAS LOST IN THE FAR NORTH.

Return of lost voyageur.

In connection with the survey of Great Bear lake, it was mentioned in the Summary Report for 1900, that one of Mr. J. M. Bell's men (Charles Bunn) had been lost near the Arctic sea. Mr. Bell and all his party did their best to obtain some trace of the missing man, but without success. They spent a number of days searching for him on the Barren Lands between the north-east angle of Great Bear lake and the Coppermine river, not far from Coronation gulf, when time was very precious, as too little of the season remained for their own return before the setting in of winter. After the party had been obliged to give up the search, Mr. Bunn fortunately wandered to a camp of Indians on Great Bear lake. These people treated him hospitably and helped him to reach Fort Norman on the McKenzie river. From this post he accompanied parties of Hudson's Bay Company's men to Fort Simpson and thence to Fort Resolution, where Mr. Bell had engaged him. He pushed on southward up the Great Slave and Athabasca rivers and finally arrived safely at Edmonton, where he was paid by this Department for all his time and expenses.

OFFICERS' REPORTS.

THE YUKON DISTRICT.

Mr. R. G. McConnell.

Yukon district.

During the past season the writer, assisted by Mr. Joseph Keele, who acted as topographer and geological assistant, was occupied principally in an examination of some of the smaller placer camps in the Yukon Territory. I left Ottawa on June 16, joined Mr. Keele, who had preceded me a few days, at White Horse on June 26, and after outfitting there, we proceeded at once to the Salmon river gold-field. The party consisted, besides Mr. Keele and myself, of two camp hands, who were engaged at Sault Ste. Marie.

Salmon river Gold-field.

Salmon river gold-field.

The Salmon river gold-field is situated east of the South fork of the Big Salmon river. It can be reached by ascending the Big Salmon river to the South fork, a distance of about forty miles, and then continuing up the latter to the mouth of Livingstone creek, a further distance of about twenty-five miles. These streams are, however, swift and difficult to ascend, and the route generally adopted is to descend the Lewes to the mouth of the Teslin, and ascend the latter to Mason's Landing, a distance of about twenty miles. From Mason's Landing, a pack trail, fifteen miles in length, has been constructed across the ridge bounding the Teslin valley on the east, to the valley of the South fork of the Salmon, and branch trails continue on to the various creeks. The trail follows a wide depression in the ridge mentioned above, at the summit of which it reaches an elevation of about 1,700 feet above the Teslin valley. A wagon road, following nearly the same course across the ridge, could easily be constructed and would be a great boon to the district.

Topography.

Topography.

The topography of the district is simple. A ridge about five miles in width where crossed by the trail, separates the Teslin river at this point from the valley of the South fork of the Salmon. The ridge is traversed by several deep depressions and is fairly regular in outline as a rule, but in places is surrounded by rocky peaks, some of which attain an elevation of 5,000 feet.

South fork.

East of the Teslin ridge is the great valley of the South fork of the Salmon, a huge depression some thousands of feet in depth, and where crossed by the trail, nearly two miles in width. The valley-bottom consists of a wide, partly forested gravel plain, broken in places by low benches and terraced along the sides up to an elevation of about 500 feet. The South fork itself is a shallow stream, seldom exceeding thirty yards in width, flowing rapidly along a boulder-paved channel. It rises in a range of granite mountains to the south and has a length, measured along the valley, of about sixty miles. Its grade at the mouth of Livingstone creek averages forty-five feet to the mile.

East of South fork.

The valley of the South fork is bordered on the east by a steep slope, about 2,000 feet in height, beyond which is a strip of plateau-like country, four to five miles in width, surmounted by low rounded hills, the summits of which have an elevation of from 2,000 feet to 2,500 feet above the valley. The plateau-strip is terminated on the east by a high mountainous district, worn into sharp peaks and bold projections, on some of which the snow lies throughout the season. The plateau-strip bordering the valley constitutes the gold-field of the district. The larger creeks cut back through it into the high mountain region beyond; the smaller ones rise in the lower foreground and descend rapidly, often in a series of cascades, to the level of the valley of the South fork.

Timber.

The valleys and the slopes of the plateau, up to a height of about 2,000 feet above the valley of the South fork, are partially forested. The principal trees noted were the Banksian pine, the white and black spruces, the aspen, the rough-barked poplar, the balsam fir and a species of birch. The trees, as a rule, are small and the quantity of serviceable timber in the immediate vicinity is limited. A few groves of white spruce were noted, some individuals of which attained a diameter of fully eighteen inches, but trees of this size are rare.

Geology.

The geology of the district can only be briefly referred to here as the rocks have not been studied. The oldest beds in the district consist of hard micaceous quartzites, passing into mica-schists. These rocks are exposed along the eastern slope of the mountains referred to above, as bounding the auriferous plateau on the east. They are interbanded towards the top with crystalline limestones and are overlaid by green chloritic schists, probably representing crushed diorites or diabases. The green schists are followed in ascending order by gray quartz-biotite schists, white and light gray sericite schists, ressembling the gold-bearing schists of the Klondike series and probably like them of igneous origin, lead-coloured argillites, a second series of green rocks, mostly tuffs, above which is a wide band of hard cherty limestone forming the western edge of the plateau. The schists and associated quartzites and limestones have a nearly north and south strike and dip steadily to the west at angles of from 20° to 50°.

Character of rocks.

The high narrow plateau bordering the valley of the South fork on the east, in which most of the gold streams of the district have their sources and which all of them traverse, is thus seen to be built almost entirely of micaceous schists of various kinds, and from these rocks the gold of the district undoubtedly originated. The schists are partly of igneous and partly of clastic origin and resemble in a general way the gold-bearing schists of the Klondike district.

Origin of gold

The ridge between the South fork of the Salmon and the Teslin river is built of comparative recent volcanic rocks consisting largely of andesites, augite-porphyrites and allied varieties. Basalt occurs at the base of the western slope, and tuffs and agglomerates on the eastern slope.

The schists east of the South fork are cut, south of Mendocina creek, by some dykes and a couple of small bosses of gray biotite granite. This rock is not conspicuous in the district, but is apparently widely distributed further to the south, as the wash in the South fork is largely granitic.

Granite.

Gold-bearing Streams.

Gold has been found in some quantity on all the streams traversing the high plateau, previously described as occurring east of the South fork, along a stretch about twelve miles in length extending from Sylvia creek to Mendocina creek. The schists which underlie this portion of the plateau continue on both to the south and to the north and it is probable that the field will be extended as prospecting continues.

The most productive stream so far discovered is Livingstone creek. This creek has a total length of ten miles. Its general course is

Livingstone creek.

westerly, but four miles above its mouth it enters an old longitudinal valley which cuts off a segment of the plateau, and turns abruptly north for two miles before crossing the flats to join the South fork. It is a fair-sized stream, measuring about fifteen feet in width at ordinary stages of the water, where it leaves the hills. The current is very swift, as the grade is steep, exceeding 400 feet to the mile in some places.

Character of rocks.

The valley of Livingstone creek differs considerably in character from that of the Klondike creeks. In its upper part, it is a deep, rounded depression, evidently modified by glacial action, terminating in a steep-sided amphitheatrical basin. Farther down, the valley narrows in and becomes a canyon bounded by steep rocky walls separated at their bases by a narrow flat from 50 to 100 feet in width. The canyon portion of the valley has a length of about three-quarters of a mile and ends abruptly at the old valley previously referred to, which the creek enters after leaving the plateau.

Gravels.

The workings on Livingstone creek so far have been confined principally to the canyon portion of the valley. Discovery claim, on which the most work has been done, is situated near the head of the canyon. The gravels here and along the canyon generally are quite shallow, seldom exceeding three feet in depth, and in places the bed-rock is bare. They are, unlike the Klondike gravels, only partially derived from the rock exposed along the valley, and include much foreign glacier-borne material, largely of a granitic character. Boulders are numerous and are often of large size, some of them measuring six to eight feet or more in diameter. The heavy grade of the valley renders hydraulicking practicable, and on Discovery claim the water is flumed along the bank until a head of about fifty feet is gained and it is then used to ground-sluice the light wash in the bed of the stream. The heavy boulders are removed, when necessary, with a derrick.

Character of gold.

The gold is found principally on bed-rock or in the crevices of the rock and as a rule is very coarse. A third of the gold obtained from Discovery claim consisted of nuggets over an ounce in weight, and none of it, I was informed by the manager, could be called fine gold. The largest nugget obtained was valued at $304, and the second largest at $295, assuming the gold to be worth $16 to the ounce, the ordinary price. The assay value of the gold is stated to average $18.20 to the ounce. A few of the nuggets show a rough surface and include fragments of quartz, but as a rule they are worn quite smooth. This is probably due largely to the attrition of the sediment in the stream, as it is impossible that gold of this character could have been carried for any considerable distance.

Discovery claim is stated to have produced $11,000 in 1900, and a small amount in the preceding year. The product of the present season was not ascertained, but the 'clean up' which was made at the time of my visit was very satisfactory and the output for the season will probably be considerable. The ten claims below Discovery claim and extending from it down to the foot of the canyon are very similar in character to Discovery claim. They are owned by a company and preparations are being made to work them on a extensive scale during the coming season.

Claims above canyon.

Very little work has been done on Livingstone creek above the canyon, as the ground is much more difficult to prospect. The gravel is much deeper, and as it is not frozen except in sheltered spots, work on the shafts has mostly been stopped before bed-rock was reached by the inflow of water. The claims will require to be drained before they can be worked and this can only be done by a company owning several of them, or by a number of the claim owners combining and working their properties in common.

Below the canyon, the creek, as stated before, enters an old valley and runs for some distance at right angles to its former course. The gravel in this portion of the valley proved to be very deep. A number of shafts have been sunk, one of them to a depth of over seventy feet, without reaching bed-rock. Work on most of these shafts was stopped by water before any results were obtained.

Summit creek

Summit creek, two miles north of Livingstone creek, and running parallel with it, is a much smaller stream, scarcely measuring six to eight feet in width where it leaves the hills. It heads in the plateau and, after a course of less than three miles, cascades down into a longitudinal valley, which here follows the base of the hills and runs north to Cottoneva creek. Its valley, where it leaves the hills, is narrow and canyon-like in character, but above the cascade it gradually widens out and assumes the form of a broad rounded and comparatively shallow depression.

Discovery claim, on this creek, is situated at the foot of the cascade. The gravels here are shallow and include, as on Livingstone creek, numerous granitic boulders. The claim is worked by ground-sluicing, water for this purpose being easily and cheaply obtained from the cascade. About $1,200 was taken out in 1900. The gold is similar in character to that from Livingstone creek. The claims above the cascade have not been prospected, although some work has been done. The gravels deepen rapidly in ascending the valley, and work on the few shafts which have been started, has been stopped by water before bed-rock was reached.

Lake creek.

Lake creek, a mile north of Summit creek, is about equal in size to the latter and its general character is very similar. Discovery claim on this creek, is situated above a cascade, which occurs, as on Summit creek, near the brow of the plateau. The gravels at this point, and for a few claims above, are comparatively shallow, averaging from four to eight feet in depth and can be easily worked. Work had only begun at the time of my visit, but some gold was being taken out and the miners appeared to be very hopeful in regard to the future of the creek.

Cottoneva creek.

Cottoneva creek, three miles north of Lake creek, is a much larger and longer stream and it has cut a more uniform grade down from the plateau. A canyon, half a mile in length, occurs about a mile from the point at which it leaves the hills. Above the canyon the valley is wide with gently sloping banks. The first discovery in the district was made on this creek in 1898, but the yield has been small and at the time of my visit no work was being done. The gravels are reported to be deep and difficult to work above and below the canyon, and in the canyon, where they are shallow, they do not appear to be productive. Besides the creeks briefly described above, good prospects have been obtained from Martin and Sylvia creeks, south of Livingstone creek, and from Little Violet and Mendocina creeks north of Cottoneva creek, and on the opposite side of the valley some work was being done near the mouth of St. Germain creek, a stream heading in the range west of the South fork.

Production of field.

The total production of the Salmon river gold-field up to, but not including the present season, was estimated at $20,000, the greater part of which has been obtained from Discovery claim on Livingstone creek. Work in the district has, however, barely commenced, notwithstanding the fact that gold was discovered as early as 1898. The field can only be considered of moderate richness and the fame of the Klondike creeks drew most of the miners to that section. The outlying camps are now, however, receiving more attention and it is expected that work in the future will be more vigorously prosecuted.

Yukon River.

Rocks along Yukon valley.

After leaving the Salmon river gold-field we descended the Lewes and Yukon rivers in a Peterborough canoe, and a few days were spent in making an examination of the geological section exposed along the Yukon valley below Fort Selkirk. Only a brief reference to this work will be made here. The rocks at Fort Selkirk and down the Yukon valley for fifteen miles consist mostly of diabases, coarse tuffs and agglomerates. These rocks are underlaid by a highly altered clastic series consisting largely of quartz-mica-schists, quartzites and crystalline limestones. The clastic series, in a more or less altered condition, occurs at intervals along the valley down to the mouth of Fortymile river and probably beyond. It alternates in broad bands with igneous schists and gneisses, derived mostly from granites, quartz porphyries and diorites. The granite gneisses have been regarded as the oldest rocks in the Yukon valley, but positive evidence was obtained during the course of the exploration that they are really younger than the altered clastic series and have been intruded through them. The old igneous schists, and to a less extent the clastic schists, are very important from an economic standpoint, as they constitute the gold-bearing rocks at all the camps so far examined. They are broken through at numerous points along the valley by intrusives of various kinds and are overlaid in places by more recent rocks, but a description of these does not come within the compass of this report.

Thistle Creek.

Thistle creek.

Thistle creek enters the Yukon from the east about eight miles above the mouth of White river. It is about eighteen miles in length and towards the mouth from fifteen to twenty feet in width. The valley is flat-bottomed in the lower stretches, the flats varying in width from 150 to 400 yards, but towards the head it narrows into a V-shaped gulch. The bordering hills have a general height above the valley of 1,000 feet to 1,500 feet, but in places slope up to sharp peaks and ridges very much higher. Terraces occur at intervals, but do not form continuous lines. The grade of the valley increases gradually towards the head. Six miles above the mouth it amounts to 50 feet to the mile, and at twelve miles to 100 feet to the mile.

Valley.

Work done.

Discovery claim on Thistle creek is situated about six miles above the mouth. The creek was staked in 1898, but the work done on it up to the present has been inconsiderable. At the time of my visit some work, chiefly of a prospecting character was being done on claims 17 and 19 below and 9 above Discovery on a terrace opposite 9 above, and at the mouth of Edas gulch which comes in opposite 12 below. The gravels on Thistle creek resemble those on the Klondike creek. They consist principally of flat schistose pebbles, imbedded in coarse sand, and include occasional boulders of quartz and granite. They have a thickness in the vicinity of Discovery claim of from four to six feet and are overlaid by a layer of muck, usually from 8 to 10 feet in thickness. The terrace gravels are coarser than

Gravels.

those in the creek and have a thickness at the rim of the bench opposite Discovery claim of 25 feet.

Gold.

None of the Thistle creek claims yet worked have proved very rich. The gold is irregular in its distribution and so far has been found principally along the left limit of the valley close to a well defined terrace which extends from claim No. 9 above Discovery down stream about three miles. The gold is found principally on or in bed-rock and occurs in coarse grains and nuggets. The largest nugget reported came from claim No. 1 above Discovery and was valued at $96. The total product of the creek is estimated at $10,000.

Henderson Creek.

Henderson creek.

Henderson creek enters the Yukon from the east about three miles below the mouth of the Stewart. It is a longer stream than Thistle creek and carries considerably more water, but is very similar in general character. It occupies a flat-bottomed valley of the usual type, bordered by fairly steep, mostly wooded, banks which are, in places, interrupted by irregular disconnected benches, but the banks are not conspicuously terraced.

Rocks.

The rocks exposed along the valley consist, as on Thistle creek, mainly of granite-gneisses and other igneous schists. At the Forks, three miles above the mouth, inliers of white crystalline limestone associated with quartz-mica-schists and quartzite were noticed, and andesites occur in a group of high rounded hills near the head of the creek.

Work done.

Only one claim was being worked on Henderson creek at the time of my visit. The creek was hurriedly and inadequately prospected in 1898 and since then has been practically abandoned. The claim which is being worked is situated about fourteen miles above the mouth of the creek and just below the junction of the main branch with Sixty-mile creek. It is owned by two Australian miners who have worked it partly by drifting and partly by the open-cut method for several seasons, and are apparently quite satisfied with the result. The gold is finer than on Thistle creek and is not concentrated near bed-rock, as is the case on that creek, but extends, like the Bonanza creek gold, upwards into the gravels for several feet. It is unlikely that this claim is the only one containing pay gravel in this portion of the valley and systematic prospecting on some of the adjoining claims would probably lead to equally good results.

Sixty-mile District.

The gold creeks of the Sixty-mile district are situated near the Alaskan boundary, about forty miles directly west from Dawson. They can be reached by ascending Forty-mile river, a western tributary of the Yukon, to the mouth of Moose creek a couple of miles west of the International boundary, from which point a good trail about twenty miles long leads to the principal creeks; or by a pack trail from Dawson, 56 miles long which follows the divide between Swede creek and the Yukon, or by ascending Sixty-mile river. The latter route is seldom used, owing to the shallowness of the stream, and the numerous bars and rapids which interrupt its course. All these routes were traversed in the course of the present exploration. The writer reached the district by Forty-mile river and the Moose creek trail, and descended Sixty-mile river on the way back in a small canvas boat which was portaged across from Forty-mile river for the purpose, while Mr. Keele travelled by the overland route and made as careful a survey of it as time permitted.

Routes to Sixty-mile district.

Geology.

The rocks in the Sixty-mile district are similar to those occurring on the Yukon valley above Dawson. The beds have a general east and west strike, and a section across them from Forty-mile river south to the Sixty-mile shows two broad bands of dark quartz-mica schists, quartzites and crystalline limestones, similar to the rocks described by me in a former report as the Indian river series, separated by a band of igneous schists four to five miles in width. The latter consist partly of gray granite-gneiss, and partly of light-coloured sericite schists derived mostly from quartz-porphyries. The schists are replaced near Sixty-mile river by andesites and are overlaid on Moose creek by a small area of conglomerates, probably of Cretaceous age.

Character of rocks.

Gold-bearing Creeks.

Coarse gold was discovered in the Sixty-mile district in 1893, and from that time up to the discovery of the Klondike creeks in 1896, it was one of the principal producing camps in the Yukon country. It was practically abandoned in 1897, but lately the miners have been returning to it. At the time of my visit, about forty men were at work.

The principal creeks are Miller and Glacier* creeks on the Sixty-mile slope, and Moose creek, a tributary of Forty-mile. Moose creek is a

Moose creek.

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* A detailed description of Miller and Glacier creeks, by J. E. Spurr, is published in the eighteenth Annual Report of the U. S. Geological Survey, pages 320-326.

large stream, about twenty feet wide at its mouth, and about fifteen miles in length. Its valley is about 200 yards wide in the lower reaches, but gradually contracts towards its head into a narrow gulch. Gold in small quantities is found all along the valley, but only a short stretch, barely a mile in length, commencing about ten miles above its mouth, contained claims rich enough to work. The gravels had a depth of from two to four feet, and the gold occurred in a narrow pay streak in the centre of the valley. The total amount produced is given at $5,000 only.

Glacier creek.

Glacier creek is a tributary of Gold creek, and joins the latter a mile above its mouth. It is a small stream, from two to three yards in width, and less than seven miles in length. The grade is steep, amounting to about 100 feet per mile in the lower part of the valley, while further up it becomes much steeper. The valley conforms to the usual type. The upper part is a narrow gulch, but in descending, it gradually widens, and towards its mouth has a breadth of 200 yards. It has been worked from claim No. 28, above Discovery, down almost to its mouth, a distance of about five miles. The pay streak from No. 21 above, down to No. 17 above, is reported to have been very continuous but quite narrow, less than twenty feet in width. Farther down it widened out and became more spotty. Claim No. 18 below is stated to have been the best claim on the creek. The valley gravels have a thickness of from six to ten feet and are overlaid, as on the Klondike creeks, by a varying thickness of black muck. They have been mostly worked over, but a few claims, too low in grade to pay in the early days, still remain, and some gold was also being obtained from a few of the richer claims which had been imperfectly or only partially worked.

Terraces.

The terraces on Glacier creek were neglected up to the last year or two, but are now being worked at several points. Well defined benches occur on the left limit, opposite claims 10 and 12 above, and on the right limit opposite No. 6 below and down the valley for some distance farther. The bench opposite No. 10 above, is interesting in as much as the workings, consisting of three shafts, one 62 feet deep, prove the existence of an old channel, separated from the present creek channel by a rock ridge 27 feet high and about 200 feet in width. The old channel has an elevation of 75 feet above the present one. Pay was found in one of the shafts, and the owners expect to work the claim from a tunnel which they are driving through the rock ridge. At claim No. 6 below, good pay has been struck on a terrace on the right limit 40 feet above the valley bottom. The gravels here have a thickness of about 50 feet.

The terrace gravels of Glacier creek are ordinary stream wash, deposited before the valley had been sunk to its present depth, and they have no resemblance to the enigmatical quartz drift or white wash of Bonanza and Hunker creeks.

Miller creek

Miller creek, west of Glacier creek, empties into Sixty-mile river. It is somewhat shorter than Glacier creek, about equal to it in size, and its general character is very similar. Miller creek was considered a very rich stream in early days, and for two or three years after its discovery, it ranked as the chief producer in the Yukon country; but it is now nearly exhausted so far as the valley gravels are concerned. Terraces occur on the left limit from No. 2 below, down to about No. 20 below. They were only discovered recently and are still practically unworked. A terrace claim opposite creek claim No. 17 below, is stated to have yielded $18,000 during the past season. The terrace here has an elevation of fifty feet above the creek bottom and the gravels have a thickness of about fifteen feet near the rim, but evidently deepen considerably, farther back.

Terraces.

Other creeks.

Other creeks in the district are Poker and Davis, both of which head in the Yukon territory, but have their principal productive portions in Alaska; and Gold creek, Twelve-mile creek and California creek, tributaries of Sixty-mile river from the north, all of which show prospects, but up to the present have afforded no paying claims. The total production of the Sixty-mile creeks is difficult to estimate at this late date, but was probably less than half a million dollars.

Derivation of gold.

The gold on Miller and Glacier creeks is derived, in large measure, directly from the quartz veins and silicified schists of the district, but some evidence was obtained in the course of the exploration, serving to show that some of it has been deposited from solution. A boulder was found in one of the workings on Miller creek, the upper surface of which was partially covered with specks and scales of crystalline gold. The crystals were arranged in dendritic forms, and while some of them were firmly attached to the rock, others separated easily from it. The angles of the crystals were sharp and showed no wear of any kind, while the boulder itself, an autoclastic quartz-mica schist, was well rounded. The gold evidently did not belong to the rock originally, and the only explanation of its occurrence under the peculiar conditions stated, seems to be, that it was taken up by some solvent and redeposited on the surface of the boulder in the position in which it was found. A number of specimens of unworn crystalline gold in filiform and dendritic shapes have been found on Eldorado and other Klondike creeks, which were probably formed in the same way, although no direct evidence of this has hitherto been obtained.

Sixty-mile River.

Sixty-mile river.

A track-survey was made down Sixty-mile river from the International boundary to its junction with the Yukon. This stream heads in Alaska and has a length, after crossing into Canadian territory, measured along the valley, of about 70 miles, and following the windings of the stream, of about 125 miles. Its fall, measured roughly with the barometer, from the boundary to the Yukon, amounts to 1,425 feet, and the average grade of the valley to a little over 20 feet to the mile.

Size of stream.

Sixty-mile river, at the Boundary, is a rapid winding stream averaging about 50 feet in width and interrupted at frequent intervals by steep bars covered with only a few inches of water. The upper portion of the river from the Boundary to California creek can hardly be considered a navigable stream even for small boats. Below California creek the volume of water increases and the descent becomes less difficult, but bars and rapids continue almost to the mouth and no part of the river is easy to ascend. The tributary streams are small, as a rule, but two large streams, one draining the country to the west and the other to the south, come in within four miles of each other, nearly opposite Indian river and these branches nearly double the volume of the main river. Towards its mouth Sixty-mile has an average width of from 40 to 50 yards.

Valley.

The valley of Sixty-mile is generally flat-bottomed, the flats varying from a couple of hundred yards to nearly a mile in width. The sides are usually terraced and in places, the stream for long distances, has cut a secondary rock-walled channel, similar to that noticed on Indian river and the Stewart, through the bottom of its old valley. The country bordering Sixty-mile river forms part of the Yukon plateau, a highland worn into rounded hills and long zigzag ridges, but containing no well defined and continuous mountain ranges. At several points, high hills usually built of andesite, project a few hundred feet above the general level.

Geology.

Sixty-mile river affords a very good geological section, but only the salient points of this can be given here. At the Boundary and down the valley to Bed-rock creek, the rocks consist principally of igneous schists of various kinds, largely granite-gneisses, with which are associated some quartzites and other clastic schists. These schists constitute the gold-bearing rocks. They are replaced below Bed-rock creek by andesites which continue down to a point a mile and a half below the mouth of Gold creek. The andesites extend up Miller creek nearly three miles and up Gold creek over seven miles. Their distribution south of Sixty-mile river is not known, but they apparently cover a considerable tract of country in that direction.

Rocks of Sixty-mile.

Below Gold creek the granite gneisses and associated igneous and clastic schists reappear and are exposed along the valley down to a point five miles below the mouth of Ofa creek. The schists, in this stretch, are cut by numerous intrusions of newer granite, and quartz veins are fairly abundant. They are succeeded by andesites, basalts and other volcanics, and these rocks, alternating with basins of sedimentary strata consisting mostly of conglomerates, agglomerates and shales, probably of Cretaceous age, continue down the valley for twenty miles. Below that point the granite-gneiss and included clastic schists and crystalline limestones appear again and outcrop along the valley down to the mouth of the river. The gold-bearing rocks, it will be seen, occupy the upper and lower parts of the valley but are covered up along the central portion by more recent and, so far as known, barren rocks. Some bars were worked in early days on Sixty-mile river, but so far as could be learnt, none of them proved very rich and at the time of my visit no work of any kind was being done.

Quartz Veins.

Quartz veins.

Considerable prospecting for quartz has been done in the Klondike district and in other parts of the Yukon country during the past season, and numerous discoveries of more or less importance have been reported. The old igneous and clastic schists referred to previously as the gold-bearing rocks and which have such a wide distribution along the Yukon valley, are cut everywhere by quartz veins and in places these become so abundant as to constitute a considerable proportion of the whole rock-mass. The majority of the veins follow the planes of schistosity or cut them at a small angle. They are narrow and non-persistent as a rule, but occasionally swell out into lenses of quartz six to eight feet or more in width. These veins often give fair assays and in places show free gold, but except in rare instances they are too small singly to make mines. The discovery of a zone of small auriferous quartz veins closely grouped together, and capable of being worked together, is however possible, and in a region so highly silicified as the Klondike district, even probable.

New Bonanza and Lone Star claims.

Before leaving Dawson, a visit was made to the New Bonanza and Lone Star claims at the head of Victoria gulch, a tributary of Bonanza creek. The development work done on these claims consists of a few shallow shafts or pits, none of which reach any considerable depth. At one of these openings on the New Bonanza, a kidney of quartz, Gold in quartz.

over six feet in width has been uncovered for a few feet, one end of which is studded with grains and nuggets of gold. A second opening, 200 feet to the south-east, has been sunk in a smaller quartz vein, also carrying free gold. A specimen of quartz from this vein, in which no free gold could be detected with the naked eye or an ordinary magnifying glass, was assayed in the laboratory of the Survey and gave 2.625 ounces of gold and 3.267 ounces of silver to the ton. The country rock, mostly sericite schists, adjoining the vein, also proved to be auriferous. Other small veins occur to the north-west, following the same south-east and north-west strike as those above mentioned. The work done on these claims is insufficient to base an opinion on as to their ultimate value, but the prospects are certainly encouraging enough to warrant further investigation.

The existence of a group of quartz veins at the head of Victoria gulch, carrying free gold in such quantities, is interesting from the fact that the pay streak on Bonanza creek practically stops at the mouth of this gulch. Victoria gulch itself is gold-bearing, and the gold obtained near its head is rough and unworn and looks as if it had just dropped out of its original matrix. It is not inferred from this, of course, that all the gold on Bonanza creek originated from this source, as the coarse gold found along this stream could not have travelled any distance, but that some of it came from this point seems beyond question.

Quartz veins on Sixty-mile river.

Quartz veins are prominent in places along Sixty-mile river and a couple of specimens collected proved to be auriferous. A vein about four feet wide cuts the granite-gneisses about a mile below Twelve-mile creek, in the upper portion of the river. A specimen from this vein was assayed in the laboratory of the Survey and yielded 0·058 ounces of gold to the ton. A vein was also found about six miles above the mouth of the river, on a bluff 200 feet above the level of the valley, a specimen from which assayed 0.117 ounces or nearly $2.50 to the ton. This vein consisted of light brown drusy quartz and at the point examined it was fully eight feet in width. It apparently belongs to a different class from the ordinary small gash veins of the districts, and is worth a closer examination, as the proportion of gold usually varies along the strike and portions of this vein may be rich enough to work.

Quartz veins occur in the schists of the Salmon river country, but the only specimens assayed from this district proved to be barren. Specimens from a vein on Fish creek, a tributary of the South fork, which carried iron and copper pyrites and gelena were shown to the writer. The vein is stated to be of large size, but it was not examined.

River Dredging.

Dredging at Cassiar bar.

Character of river gold.

Gold coarser near sources of supply.

The dredging operations at Cassiar bar, on the Lewes river, in 1900 proved a failure. About 50,000 cubic yards of gravel were washed, and the average yield, so I was informed by one of those interested, averaged only five cents per cubic yard. The bar has been abandoned and the plant transferred to a claim on Bonanza creek, where it is reported to be doing satisfactory work. Cassiar bar was worked in early days by the miners, and was supposed to offer exceptional facilities for dredging. The failure there has, on this account, led to an impression that a like result would attend dredging operations in any part of the district. This opinion, it seems to me, is not well founded. Cassiar bar is situated a long distance from the source of supply and, as a consequence, the gold is very light, and is confined, as is usual in such circumstances, to a thin layer of gravel immediately beneath the surface. The conditions are entirely different on streams or portions of streams, near to, or cutting the rocks from which the gold originates. The grains in the latter case are heavier, are less easily moved, and the gravels increase in richness, as a rule, towards bed-rock. The bars on Forty-mile river, a stream cutting the gold-bearing schists throughout nearly its whole course, afford a good example of this. The gold on the auriferous bars on this stream is much coarser than that obtained from Cassiar bar and the best pay occurs near bed-rock. The gravels on the Klondike river below the mouths of the gold-bearing creeks has been proved to be auriferous to some extent down to bed-rock, and gold, in grains much coarser than the ordinary flake gold of river-bars, has been found in the bed of the Stewart, and also on the bars of the Big Salmon. Whether dredging would pay on any of the streams mentioned, is a question which can only be answered by careful prospecting or actual work, but it is obvious that the result of a single experiment cannot be accepted as settling the matter in the negative for the whole district.

THE GEOLOGY OF THE REGION ADJOINING THE WESTERN PART OF THE INTERNATIONAL BOUNDARY.

Dr. Reginald A. Daly.

Geologist to Boundary Commission.

The government having decided to send a geologist, as a member of the Canadian Commission appointed to co-operate with the United States Commission in locating the International Boundary, which was to begin operations at the western extremity of the line last spring, I was asked to name a suitable person for the position. I recommended Dr. R. A. Daly, a Canadian, who was instructor in geology in Harvard University. He was appointed and entered upon his duties in the end of June. He reports as follows upon the season's work :—

Instructions.

On June 29 I left Ottawa to join the Boundary Commission party which was under the direction of Mr. J. J. McArthur, D.L.S. The axemen of Mr. McArthur's party had already been some five weeks engaged in cutting trails to Chilliwack lake and beyond, where the monuments of the 1859-61 Commission were to be examined and vistas cut through the forests on the line of the 49th parallel of latitude. My instructions were to use the commission camp as headquarters and to work out the geology of as broad a belt north of the International Boundary as could be reached from that camp.

A brief stay at Banff and another at Field enabled me to get a glimpse of the Canadian Cordillera and, especially of the Carboniferous, Devonian and Cambrian members of the system. While awaiting the steamer from New Westminster to go up the Fraser, I made a short visit to Victoria, where I was particularly impressed with the remarkable traces of glaciation near that city. Returning to the mainland, I arrived at Chilliwack village on July 9, but, on account of difficulties of the trail, did not reach camp at the upper end of Chilliwack lake before July 14.

Length of season.

I remained in the field until October 29, and returned to Ottawa three weeks later, by way of San Francisco, Salt Lake City and Denver. Believing that even a rapid railway trip could aid one greatly in bringing into sharper relief the contrasts and similarities of structure and of form in the mountains of Canada and the United States, I chose this roundabout route. The North American Cordillera will be understood, as a whole, only after Canadian and American cross-sections are correlated, a treatment which, for this orographic system, stands among the more pressing desiderata of present day research.

Correlation of American and Canadian geology.

The tracing along the strike of the different mountain belts from the one country to the other, offers related problems of the highest importance. Examples are to be found in the search for the equivalent, in Canada, of the Basin Ranges, as these disappear under the vast lava cap of Oregon, Washington, and Idaho, and again, in the study of the zone of transition between the physiographic type of the Canadian Rockies and the quite different type represented in the Big Horn mountains of Wyoming or the Colorado Front range. It was, therefore, with peculiar interest that, for the first time, I saw, even fleetingly, the Cascades with their associated volcanoes, the Sierra Nevada fault-block, the ranges of the Great Basin, the shore-lines of Lake Bonneville, the canyons of the Eagle, Grand and Arkansas rivers, some of the Colorado ranges and a typical Rocky Mountain 'park.' A more prolonged study was made of the classic section near San Francisco, from which the proofs have come of the extraordinarily recent origin of the Coast range of California; in making this excursion, I was directed by Professor A. C. Lawson, formerly of this Survey, and by Mr. Calkins, assistant geologist in the American staff on the International Boundary Commission. A day was spent among the modern gold-mining plants of the Cripple Creek district; a second, in visiting smelting and chlorination plants at Colorado City and Denver.

My outfit and the expenses of the season were supplied by the Department of the Interior, through Mr. King, our Chief Commissioner. I secured an excellent assistant in Mr. F. Nelmes, of Chilliwack, who helped me greatly at all times, but particularly during the more difficult climbing. Until September 17, we remained in direct communication with the main camp, but, thereafter, until October 18, we employed a small independent pack-train and camping outfit.

Conditions of work.

While the month of June had been characterized by almost continuous rain, our party was fortunate in having extraordinarily fine weather until September 1, and indeed, the meteorological conditions for field-work were favourable even as late as October 15. We were assured by the ranchers of the Fraser and Chilliwack valleys that so long a period of fair weather had never been recorded there before. Offsetting this good fortune to a large extent, work was seriously interfered with during August and part of September by a heavy pall of smoke borne into the mountains from forest-fire or ranch-clearing by the prevailing westerly winds. The smoke was usually so thick as to make photography, sketching and even intelligent mapping of outcrops either impossible or of indifferent success. The burning of the bridge across the Chilliwack river was a further cause of interruption in the progress of the work.

Difficulties.

The excessive ruggedness of the belt traversed, coupled with the well-known luxuriance of the dense Coast Range forest, its brulés, windfalls, devil's club, vine-maple and other underbrush offered, however, the greatest impediment in carrying on the work of the summer. Even under the able leadership of Mr. McArthur, our large party of axemen barely succeeded in opening the trails required to give access to the whole number of boundary monuments, before the bad weather of the autumn forced me to relinquish work in the mountains.

Construction of sketch-map.

The existing topographic maps of the region investigated were found to be entirely inadequate as a basis for geological plotting. For this reason, much time was spent in making a sufficient number of sketches, photographs and barometric readings, and in carrying on a rough triangulation, to suffice for the compilation of a 250-foot contour map of the area, on the scale of one and one-half miles to the inch.

Area covered.

The area covered during the summer includes an east-and-west belt of country eighty miles in length, parallel to, and limited on the south by, the 49th parallel of latitude, with a breadth of 10 miles north of this line. It stretches from the Gulf of Georgia at Point Roberts to a meridian running about four miles east of Chilliwack lake. Approximately the eastern half of this belt is mountainous, lying entirely within the western versant of the Coast range. The western half covers the flats of the Fraser delta and the waters of Semiahmoo bay. The first mentioned division comes within the drainage system of the Chilliwack river, and includes Chilliwack lake, the deep canyons of Middle (or Nesaquatch), Slesse, Tamihy and other creeks tributary to the river. The intervening mountain ridges, with part of the lofty Cheam range and the isolated Sumass and Chilliwack mountains rising out of the Fraser valley alluvium, claimed most of my attention for the season. The relative accessibility of the western half of the area, the simplicity of its formations and the absence of important outcrops of bed-rock, warranted a comparatively rapid study of the flats.

Geological conclusions

The following remarks are not intended to be so much a summary of results, as a preliminary statement of certain general conclusions which will receive amplification when the topographic sketch map is completed, the plotting of geological observations accomplished, photographs developed and specimens examined in the laboratory.

Considering the whole length of the transmontane section that lies before the geologist of the commission, this season's work was disappointing as to the amount of ground covered. The lack of trails on the eastern slope of the Coast range forbade my carrying the section farther east this year. The enforced concentration of field-work on the area actually covered was, however, a great advantage in reaching final conclusions as to the structure and age of the rocks within it.

The staple rocks of the Coast range are metamorphic. In the earlier reports of this Survey they bear the general name of the 'Cascade Crystalline Series.' Among the localities where metamorphism has least affected the rocks, allowing original structures and organic remains to persist in recognizable form to the present day, the long section of tilted shales and limestones briefly described by Bauerman, in the Chilliwack River Valley* seems to promise more information concerning the geological history of the southern portion of the range than any other section yet discovered. It was, however, only after seven weeks of search that the first fossil was found, and toward the end of the season that the most important faults and folds were determined in a satisfactory way. The more open country of the Skagit valley and still farther eastward will, I believe, permit of much more rapid reconnaissance.

Scenery of the belt.

By a curious accident, the International boundary line, roughly speaking, divides the Coast range into two parts of contrasted scenic quality. In Washington the summits are the higher and more peaked, the ridges the more serrate, while all are dominated by the majestic cone of Mount Baker; on the Canadian side the massifs are somewhat lower, are more rounded and less abundantly supplied with a perennial snow-cover. While this is true, the panoramas along the Chilliwack river are, nevertheless, most imposing. The inaccessible horn of Slesse mountain, 7,700 feet in height, is the loftiest peak of the belt, and the average height of some fifty other summits, determined barometrically, is over 5,500 feet. They win impressiveness in rising either from the floor of the Fraser valley, a few score of feet above the sea, or from the deely incised tributary valleys. The slopes flanking the canyons may be those of almost sheer precipices, 500 to 2,000 feet in height, or the usual ones of about thirty-five degrees.

Origin of the relief.

All indications point to the fact that erosion is responsible for the existing form of these mountains. No constructional surface, other than those slopes assumed by moving rock-waste have been recognized in the belt; no fault-scarp or fold recent enough to have preserved any of its original form, even in a damaged condition, has been observed. Vigorous dissection by denuding agencies has removed a vast volume of rock from the structurally complex range. Yet the existing *diversity* of relief cannot be far from the maximum due to the cycle of degradation through which the mountains are now passing.

Glacial erosion.

A special cause for their ruggedness is found in the erosive activity of now vanished local glaciers, for the sierras and horns have been developed in harmony with the growth of numerous high-lying cirques, amphitheatres, cols, and deep reëntrants which appear in all parts of the region. The latter forms are believed to have been formed, or at least greatly enlarged, from once shallower depressions by local ice sheets of glacial times. The glaciation of the belt does not seem to

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*Report on the Geology of the country near the Forty-ninth Parallel of North Latitude West of the Rocky Mountains, from observations made in 1859-61. Published in the Ann. Rep. of this Survey for 1882-4.

Denudation.

have been general at any time. The restoration of the rock material which has disappeared from corrie or col or deepened valley, would afford much more rounded contours and profiles than those now existing. We should probably have something approaching the full, swelling outlines of the unglaciated, deeply decayed, granitic mountains of Colorado, smooth slopes mantled with graded rock-waste. If those slopes were attacked by valley glaciers, as the glaciers of Switzerland and Alaska are now working, not only removing the pre-glacial cover of disintegrated rock, but deepening and lengthening valleys, heightening and driving backwards the head walls of ravine and corrie, there would result in Colorado a serrateness of topography perhaps as great as that over much of Washington or British Columbia.

Cirques.

Many of the corries in the belt are of extreme picturesqueness. Below magnificent head-walls and lateral precipices, one to two thousand feet in height, are to be found in several cases, rock-basin lakes or tarns; above are perennial snows capping the surrounding peaks which stand in pleasing contrast to the rich and heavy masses of evergreen forest in the tree zone. At the southern end of Chilliwack lake, I found a fine example of what may be called 'tandem cirques.' In this case two stately amphitheatres occupy the same valley, one above and *en axe* with the other. The upper one holds a true tarn; the lower is drained by a series of cascades into the lake. Another and a finer association of this kind was examined with ease from a trail between Slesse and Middle creeks, and leading to a gold property now being exploited by Mr. G. O. Pierce, at an elevation of 5,000 feet. Here three tandem cirques of considerable size succeed each other through head-wall descents of 1,000 and 300 feet. Two of them are occupied by rock-basin lakes.

Observations were made which warrant further inquiry on the question, whether the excavation of corries by glaciers is in any necessary relation to a combination of definite jointage and massive structure in the underlying rock, or at any rate, whether excavation leading to the peculiar forms of corried mountains, be not much facilitated by that combination. The best, if not all, the well defined cirques of this belt, were found either in the massive granite or massive diorite, which in both cases, seem to offer an overriding glacier much advantage in *plucking* out the joint blocks. The process of plucking undoubtedly plays an important part in all glacial erosion; in the formation of cirques it may thus assume special prominence.

Mountain tarns.

Nothing is more striking in connection with the tarn-basins than the plain evidences that in the development of each one, the respective glacier moved uphill over the lip of the basin and with enough live energy to score and groove deeply its *moutonnée* surface. The smallest tarn visited was less than 300 feet in diameter, and from the size and position of its corrie, the glacier responsible for both must have been very small. Yet it moved with grooving power for a distance of fifty feet up a twenty-eight degree slope forming part of the lip of the basin. Similar observations were made elsewhere.

The elevation of the summits within the belt is not sufficient to permit of the flourishing of large glaciers at the present time, though a goodly number of fair size are to be found among the jagged peaks just across the boundary line. None in the belt is more than a quarter of a mile in length.

Origin of Chilliwack lake.

One of the most noteworthy constructive effects of the former glaciation is seen in Chilliwack lake, which owes its origin to a heavy morainal dam. Though only five miles in length and a little over one mile in breadth, this sheet of water must, for the grandeur of its setting, rank among the finest in the Dominion. It has some resemblance to Lake Lucerne, but, in the larger features of colour and form in forest, crag and glacier, the panoramas of the Canadian lake are certainly the superior. Some day, perhaps not far distant, it should be a favoured objective point for tourist travel. The moraine holding in the waters at the lower end of the lake, is a faintly crescentic accumulation of large granite boulders without any considerable intermixture of finer materials. It rises steeply from thirty fathoms of water to a rather even crest, 100 feet above the lake-level. Its length is about 2,000 yards, its breadth 500 yards, though it may be said to merge into the less definite deposits lower down. The moraine was built at a late stage in the history of a great west-flowing local glacier, the scorings of which were observed on both sides of the Chilliwack valley, at all elevations up to 5,200 feet above the sea. This thick tongue of ice may have been a distributary of the Cordilleran ice-sheet shown by Dawson to have covered the interior plateau in glacial times.

Description of Chilliwack Lake.

The lake is deep. Forty-four fathoms of water were found not far from the shore. Owing to a lack of sufficient line, I was not able to complete enough soundings to give either the maximum depth or the shape of the bottom. It is hoped that this, with a similar study of certain of the tarns, may be accomplished next season. Strong deltas at two of the inflowing streams and numerous alluvial cones about the lake, show that it is being rapidly filled. The lake is about 1,850 feet above the sea; the granite walls surrounding it rise steeply and abruptly from the water's edge 3,000 to 4,500 feet higher. If we may judge from the truncation of spurs lying between the tributary gulches, glacial erosion seems to have given its present fiord-like character to the valley. What originally fixed the axial trend of the valley, may, perhaps, never be told, yet there is a marked parellelism between it and a system of master-joints in the granite, which suggests an adjustment analogous to that of a subsequent stream on a belt of soft rock in a tilted sedimentary series.

River terraces.

Excellent land for farming purposes occurs on broad heavily timbered benches extending from the lake dam, or a little below it, to the Fraser flats. The bench form is due to the terracing of glacial gravels, sands and clays by the torrential river. The material thus removed from the valley, together with similar products from side valleys, have been carried through a narrow 'iron gate' or rock-gorge, where the river debouches from the mountains, and there built into a flat alluvial fan. The apex of the fan is about seventy-five feet above the flooded Fraser, and its radii extend five miles or more to Sumass mountain. The size of the fan recalls the still larger fan of the Bow River and the finely mapped examples on the flanks of the San Bernardino mountains, California. By the vigorous growth of the Chilliwack fan, several small streams flowing northward between Vedder and Sumass mountains have been dammed up and Sumass lake is the result. Although possessing in time of high water, an area of about fifteen square miles, this lake is in all parts usually under ten feet in depth, excepting in the channels of inflow and outflow. In late summer, the maximum depth decreases to less than six feet and the area diminishes accordingly. A plan to drain the lake and, by suitable dyking, to reclaim not only its bed but enough of the surrounding land subject to freshets to make a total of thirty thousand acres, has been developed and needs only capital to bring it to a successful issue. The engineering difficulties can be evercome with an expenditure that is small compared to the great value of this particular land. The latter is probably as rich as any part of the Fraser valley, and needs no clearing, since it is either prairie or lake bottom to-day. The tract further enjoys the advantages of proximity to growing markets and of being part of the limited farming land of British Columbia. Capitalists will do well to examine the project with experts on the ground. One of the chief hindrances to the successful prosecution of the scheme, is the strong flooding of the Chilliwack, which obeys the law of streams on their alluvial fans of periodically shifting its bed from one to another radius of the fan. The expense of securely dyking in the river could, however, be partly compensated for by the cheapness of the water-power for pumping, dredging or other purposes; some forty feet of fall in the river may be secured for turbines and would furnish a great store of energy.

Fan of the Chilliwack river.

A fortnight was spent in a rapid study of the Fraser delta, utilizing the river-banks, the sea-cliffs near Blaine and at Point Roberts, the

Yale wagon-road, and the railroads intersecting the belt. The chief result was to show that the delta is compound in nature. At Huntingdon, at 'Mount' Lehmann, at Point Roberts, across the river from New Westminster and elsewhere, are broad flat-topped plateaus of washed gravels and sand with associated local patches of typical till. The average height of the plateaus is about two hundred feet. They are considered as remnants of a great accumulation of débris, partly alluvium, partly ice-laid drift, spread out over the lower part of the Fraser valley in glacial times, after the manner of delta-growth in front of Alaskan glaciers at the present time. Post-glacial uplift has enabled the powerful distributaries of the river to cut to pieces the original delta, so that now but small portions of its surface are to be seen. The process is thus related to the strong terracing of the upper part of the Fraser valley. The prairies about Ladner's Landing are situated on the newer delta which is now advancing rapidly into the Gulf.

Fraser delta.

For reasons already stated, this report must be particularly brief with respect to the geology of the fundamental rocks or in any discussion of the mining prospects of the belt. What appears to be the oldest formation in the area is represented in a series of coarse and finer-grained, plicated quartz-hornblende gneisses associated with diorites. They occur along the western base of Vedder mountain in the form of a narrow band of rock, limited on the north-west by the alluvium of the flats. Overlying the gneisses—doubtless unconformably—is an extremely complex group of feldspathic sandstones, grits, conglomerates, shales and quartzites, the last being of a characteristic green colour on exposed surfaces. They have as yet yielded no fossils, but the somewhat peculiar nature of the sandstones and quartzites suggests the correlation of the series with a much greater development of similar rocks outcropping abundantly in the walls of the Tamihy Creek canyon. These latter beds, too, have afforded no fossils. They underlie unconformably a third series of rocks, consisting of black and gray shales and bluish-gray, semi-crystalline limestones aggregating over 2,500 feet in thickness. Both shales and limestones have furnished organic remains.

Bed-rock geology.

The shales in the upper part are abundantly charged with molluscs, brachiopods and crinoids in so poor a state of preservation that they prove as yet simply the Palæozoic age of the strata. The overlying limestones, some 800 feet in thickness, hold the same or closely allied species. They are filled in certain zones with thick concretionary knots, lenses and reticulate masses of chert which may possibly yield microscopic forms of interest. No closer determination

Fossils.

of the age of these beds can be announced until the specimens have been examined in Ottawa. Topographically, the heavy limestone is the most important member of the series; it has a tendency to form strong ridges, scarps or bluffs, wherever it crops out in the belt.

Folds.

This limestone composes the summit, 6,500 feet above the sea, of the so called Black mountain (really whitish), a conspicuous peak between Slesse and Tamihy creeks. With the underlying shales and green metamorphics, it has been flexed into a rather regular S-shaped fold similar to an Appalachian zigzag. The pitch of the axes is directed due east. The nose of the anticline is found at the point where Slesse creek empties into the Chilliwack and the river flows westward for some nine miles in the unroofed anticline. The unexpected discovery of such an axial direction for these great folds may throw some light on the determining cause for the east and west course of the broad Fraser valley from Hope to the sea.

Faults.

The northern limb of the anticline composes part of the thick monoclinal series described by Bauerman in his section up the river. The remainder of the section is made up of the same shales and limestones repeated some four times by north-west and south-east step-faults with downthrows to the south-west. Abundant large crinoidal stems, similar to those occurring on Black mountain were discovered in the crystalline limestone at Thurston's ranch opposite the mouth of Slesse creek. It was the five-fold occurrence of this thick, easily recognized bed which at length pointed to a series of parallel faults as responsible for the duplication of beds in the twenty-mile monocline of the river valley. Duplication by overthrown folds proved to be highly improbable. In some cases planes of slipping were actually seen. The great thickness of 24,000 feet, given to the series by Bauerman, is believed to be very much in excess of the real strength of the beds. A careful, close estimate cannot be made until the map is completed and observations are plotted, but the total thickness must be less than four thousand feet.

Indications of gold and silver.

A small patch of mineralized ferruginous schists and saccharoidal crystalline limestone was discovered in contact with intrusive granite in the extreme eastern portion of the belt. It is possible that they represent the altered equivalents of the Palæozoic beds above described. There are indications of the occurrence of both silver and gold east of Chilliwack lake, and that portion of the belt can be especially recommended for exploration by prospectors. Until our trails were this summer cut through to the lake, almost no prospecting had been done in the upper part of the valley. Through July and August, a few men advanced eastward beyond the granite, and also reported the country to be worthy of close examination. The re-opening of the old Boundary Commission trail would make the latter possible. It is to be hoped that this tract, which is specially interesting to the geologist, will be rendered accessible next year by means of a suitable pack-trail.

Structures south of the Chilliwack river.

The long monoclinal section is confined almost entirely to the north side of the Chilliwack river. From that stream to the boundary line, the structures are more complex. The shales are represented by phyllites and slates, often impregnated to a remarkable degree with pyrite and other minerals; the sandstones are altered to quartzites and schists. All the sediments exhibit a degree of induration and mineralization much in excess of that displayed north of the river. This difference is to be explained partly by more intense local crumpling, and partly by the contact metamorphism of intrusives.

Eruptive rocks.

The shales and limestones are cut by a considerable number of eruptive rocks, all intrusive with the exception of an amygdaloidal lava which appears in small patches on the rugged peaks west of Tamihy creek. The latter rock, with associated tuffs, is possibly contemporaneous with the shales. The most important intrusive from the standpoint of area covered, is an extensively developed hornblende biotite granite, already noted by Bauerman, in the eastern part of the section. Its contacts were located throughout the area, and its intrusive character clearly proved. Its numerous basic segregations, the accompanying aplitic and lamprophyric dykes and metamorphic aureole well deserve detailed study. Quartz veins of good size are comparatively rare, either in the granite or in its contact zone, but coarse pegmatites are common there.

Occurrence of gold.

The granite is also intrusive into an irregular mass of variable diorite occurring between Sleese creek and the lake. The exomorphic zone of the diorite is still more interesting than that about the newer eruptive. Observation seems to show that the concentration of gold in the quartz leads, now being developed in the region, may be referred chiefly to that zone. Free gold in paying quantities, according to samples, has been found several miles from any visible granite contact, but never, to my knowledge, at any great distance from the intrusive diorite. Igneous dykes cutting the diorites, together with others among the sedimentary rocks of the belt, will be microscopically examined in Ottawa.

A few years ago, great excitement was created among mining men by the discovery of the 'Lone Jack' gold property on Red mountain, and about four miles south of the point where Slesse creek crosses

Mount Baker.

the boundary line. The net result has been to give the Mount Baker mining district a greater reputation than it at present deserves, if we may judge by the amount of production yet achieved. A small amount of free-milling high grade ore and a large quantity of low grade ore distributed in many narrow veins, is now in sight in the large number of claims staked off on the United States side of the line. On the Canadian side, only one property, that of Mr. Pierce, already noted, is being developed with an annual expenditure greater than the assessments. Mr. Pierce's assays average over forty dollars to the ton of the free-milling metal. Not only has he a tolerably rich quartz lead, but his property includes an extensive belt of an interesting auriferous rock which I take to be an altered limestone. This rock will undergo detailed study in the laboratory. A further encouragement to Mr. Pierce's enterprise is an abundant supply of water-power on the ground. Numerous other claims were visited, but, either on account of the small quantity of ore in sight, or because of its low grade character, none of them seemed so promising as this one. The strongly mineralized rocks, such as appear in the vicinity of the 'Lone Jack' mine, extend but a short distance (from one to three miles) into Canada; we must, therefore, not expect many important discoveries of the precious metal within the ten-mile belt explored this season. A ten-feet bed of magnetic iron is reported to have been found at the close of the season on Red Mountain, a few hundred yards north of the line, but I had no opportunity of reaching it in its remote position from any trail.

Plant bearing beds.

No stratified bed-rock formation later than the Palæozoic series appears in the belt except a small patch of coal-bearing shales, sandstones, grits and conglomerates, probably Cretaceous, occurring on Sumass mountain, and on the opposite ridges to the north and south of the Chilliwack river. The thickness is considerable—1,500 feet —but the area is small, not more than five or six square miles. A few fossil leaves were found *in situ*, and better specimens were presented to the Survey by Mr. D. G. Gray and Mr. M. McArdle. Mr. Gray is the manager of a boring plant which has already sunk one hole 530 feet deep in the search for coal and is continuing operations on the southeast side of Sumass Mountain. The thickest coal-bed known to me here measures thirty inches. The logs of the borings are not yet accessible to the Survey; they may show the presence of a heavier deposit. The quality of the coal is at least fair, as some of it has been successfully used for blacksmithing purposes. In this case, also, the exact age of the beds cannot be made out until the fossils have been determined, but the similarity to the Cretaceous rocks of Nanaimo is strong. The measures lie at the base of the series which has everywhere gentle dips and repose unconformably on contorted gray quartzites and hard sandstones composing much of Sumass Mountain. The latter are cut by a fine-grained diorite which is associated, in the form of a remarkable flow-breccia, with a newer granite. The coal measures overlap the breccia.

Summary of bed-rock geology.

The following is a provisional summary in descending order of the different formations in the belt, the nomenclature of which must not, however, be considered as that which may be adopted in the fuller final report:

Glacial and recent deposits.
Cretaceous (?), plant-bearing beds with overlying beds conformable with them.
Intrusives of Sumass Mountain.
Fossiliferous Palæozoic beds with others conformable with, and underlying them.
Green quartzite series.
Vedder Mountain gneisses.

Ages of dykes.

The ages of the large number of dykes in the area and of the intrusive granite and diorite of the mountain tract, are not yet known with a degree of confidence that would warrant their assignment to definite geological epochs. Using only the information to be derived from this particular region, they are to be referred to the long interval between the Palæozoic stage represented and the glacial period. The bearing of the facts ascertained by field-study this season on the question of dates of the various epochs of mountain-building in this part of the Coast range, will be discussed in the final report.

THE BOUNDARY CREEK DISTRICT, BRITISH COLUMBIA.

Mr. R. W. Brock.

Start for field.

The winter and early part of the summer were spent in Heidelberg, Germany, in studying, microscopically, rocks collected during preceding seasons in West Kootenay, B.C. On returning, I reached Ottawa on August 9, but was delayed until the 12th in getting the necessary supplies for field-work. On this date I left Ottawa with instructions to extend the work into the Okanagan map-sheet from the western border of the West Kootenay sheet, where work was left off last season. Mr. Leach, who had charge of the topographical work in West Kootenay, having been transferred to the coal-fields of the Crow's Nest Pass, I was this season without a topographer, and progress in the work was necessarily slower.

Greenwood was selected as headquarters and work was confined to portions of the Grand Forks and Kettle river mining divisions of the Boundary district. Commencing field-work at Grand Forks, Hardy creek was ascended to Hardy mountain, and the country between July creek and the North Fork of the Kettle river to the international boundary line was examined. From here the work was extended northward to Summit camp. From this point the area between Brown creek and the North Fork was examined. Moving southward, the district between July creek and Boundary creek was examined a short distance south of Wellington camp. From Wellington camp, July creek was descended and camp was moved to Grand Forks. From Grand Forks, a trip was made up the main North Fork of the Kettle river, to examine the rocks in which coal had recently been discovered.

Areas examined.

On returning to Grand Forks, work was extended from July creek to Boundary creek, south of Wellington camps, to the boundary line, including Central and Attwood's camps. A traverse was then made of the Columbia and Western railway, between Midway and Grand Forks, the railway cuttings affording fine exposures of the rocks of the district. Ordinary field-work was suspended on October 23, the remainder of the season being devoted to an investigation of the ore-bodies of the district examined, together with some of the representative ones of Deadwood and Copper camps. I returned to Ottawa on November 13.

The district between the North Fork of the Kettle river and the main stream south of Pass creek, while mountainous, is lower, less rugged and more open than the country to the east. The mountains take the form of comparatively even rounded ridges, scarcely exceeding 5,000 feet in height, often with broad summits and rather gentle slopes. The northern slopes, where they have escaped forest fires, are always well wooded, and the eastern slopes generally so. Southern slopes, as a rule, are open and grassy, and the western, either grassy or park-like. To a large extent the country is drift-covered, with knees and elbows of rock protruding. North of Pass creek the mountains are higher, rising in pyramidal peaks to a height of about 7,500 feet, and the country is less open and more rugged.

Physical features.

The climate is drier than that of West Kootenay. This, with the lower altitude of the mountains, the consequent lighter snowfall and more rapid melting in the spring, makes the water supply less copious and reliable, although the district is still fairly well watered. The valleys, as a rule, are large and wide, affording, in a number of instances, good ranching lands. The valley of the main North Fork, as far as the junction of the East Branch, was described in the

Summary Report of last year. From this fork northward, the valley is narrow and for the most part V-shaped, but widening at intervals with a small flat or swamp in the river bottom. July creek has a short deep valley with an even gradient.

Boundary creek occupies the principal longitudinal valley between the North Fork and the main Kettle river. Along its lower stretch it is a wide U-shaped valley, with good grazing land on its lower slopes. The transverse valleys are short and steep but still larger and older looking than the corresponding valleys in West Kootenay. The topography, as a whole, is that of an older mountain district.

Timber.

Most of the valleys are or have been well wooded. The timber of the North Fork is the largest and most valuable, both for mining and building purposes. The vegetation is similar to that of West Kootenay outlined in the last Summary Report. The open hillsides are usually clothed with bunch-grass, and sage-brush was observed at one or two localities.

Geoligical description.

Although this district may be traversed with less difficulty than West Kootenay, geological work is not much easier, as the covering of drift in many places conceals the rocks and good exposures are found with difficulty, if at all. Frequently the critical points, such as contacts, are entirely drift-covered. While prospect pits are usually to be found, these are not altogether satisfactory for geological purposes, for mineralization obscures the original structure, as it alters the original character of the rocks. After a few words on the nature and distribution of the rocks, a short account of the occurrence of ores in them will be given. As in the Kootenay district, the geology is complex and diversified.

Rocks observed.

Eruptive rocks (greenstones, granites, various intrusive dykes, tuffs and lavas, etc.) have the widest distribution. Sedimentary rocks, such as limestone, generally crystalline, argillites, quartzites, together with metamorphic rocks including serpentines, are met with in almost all parts of the district, but do not have very large dimensions in any one place, being caught up as inclusions in the intrusive eruptive rocks. The oldest rocks recognized in the district are the sedimentary and crystalline ones.

Crystalline schists.

On Observation mountain near Grand Forks and on the rounded hill a little south of west of this and some of the hill-sides on Newby's ranch, are crystalline mica and hornblende schist with a few bands of crystalline limestone. These highly altered rocks resemble lithologically those of the Shuswap series (Archæan), but may only be the argillites and limestones found elsewhere,in a more metamorphosed form.

Sedimentary rocks.

The argillites, in places altered to schists and hornfels, limestone, usually crystalline, often highly so, quartzite, the latter occurring only sparingly, together with serpentine which occurs in many portions of the district associated with these, form a groups which closely resembles the Cache creek series described by Dr. Dawson* and assigned by him to the Carboniferous. In the Boundary creek sedimentary rocks no fossils have been found, but they are probably of about the same age as similar rocks occurring to the north and west, and may, on this ground, be provisionally classed as Carboniferous. Owing to their mode of occurrence their strike is not uniform. It may be in any direction but most frequently perhaps it approaches north and south.

Greenstone.

Somewhat newer than the sedimentary rocks, but probably with no very great lapse of time intervening, are the greenstones, which have the greatest development of all the rocks in the southern portion of the area examined. These rocks in the district under discussion appear much altered. When the structure can be plainly seen it seems to be an augite-porphyrite, similar to that found in so many portions of the West Kootenay district. In many places it, like the West Kootenay rock, appears to be an agglomerate. Usually it is massive, but under pressure it has in places become more or less schistose, and difficult or impossible to distinguish microscopically from some of the included argillites. It cuts and holds inclusions of the older sedimentary rocks. Indeed, in most of their occurrences, these latter appear simply as islands of greater or less size, caught up in this greenstone. In places, particularly near a contact with limestone, it is almost filled with small fragments of the rocks through which it has cut.

Occurring with it, as at Summit City on the east road to Eholt and at Phoenix are areas of a tuff-like rock. The material is green, resembling the porphyrite, the fragments, which are usually angular often with protruding corners, are of limestone (crystalline) cherty quartz, red and black argillite, and are usually tumultuously arranged. They vary greatly in amount and size. Sometimes they form almost the entire rock. In these rocks are fine-grained bands resembling volcanic ash. Before these rocks have been studied microscopically it is impossible to draw a line between the greenstone filled with inclusions of the older rock and these bands of apparent tuffs. At one or two points, such as near Mile-post 72 on the Columbia and Western railroad, is a massive looking rock, full of pebble-like fragments which might prove when studied microscopically to be an associated conglomerate. Whilst, therefore, at some points there is doubt as to the nature of the 'pudding-stone' like rock, at most points it is probably greenstone filled with inclusions, with, in places, associated tuffs.

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* Annual Report, Geol. Surv. Can., vol. VII., (N.S.), Part B, pp. 37-49.

Gray granite.

Newer than and cutting the greenstone is a gray hornblende-biotite-granite which has an important development on Boundary creek at Greenwood. Small intrusions of it occur in Wellington camp and on Hardy mountain. Near its contact with the greenstone and where its mass is small it is often coarse-grained, more basic, (as if it had absorbed basic material from the older rock) and inclined to be pegmatitic. Owing to differentiation, facies of this rock also occur which are not, strictly speaking, granite. Granite porphyry dykes from it cut the older rocks for a considerable distance from the parent masses. A crushed porphyry dyke on the south fork of McCarren creek and at Central and Attwood camp may belong to this series of dykes. It will probably prove to be the same rock as the Nelson granite of West Kootenay* and about Jurassic in age.

Younger granites.

Near Central camp are exposures of a gray monzonite-like rock and dykes of a similar rock occur in the gray granite near Greenwood and in the greenstone at the Ruby claim. Whether this rock is related to the Rossland monzonites and therefore newer than the gray granite, or whether only facies of the grey granite and its dykes, has yet to be determined. A pinkish acid granite newer than the gray and belonging to the rock largely exposed on the divide between the East Branch and the main North Fork of the Kettle river, occurs on the latter about 10 miles above the fork of the East branch. On the North fork of the Kettle river there also occurs a still newer rock, a reddish porphyritic granite similar in appearance to the Rossland granite.

Dyke rocks.

Dykes of a reddish or yellowish porphyry with a fine-grained granular ground-mass and rosette-like phenocrysts of feldspar, with some of biotite, are common, especially in the neighbourhood of ore deposits. On the Carbonates claim this reddish porphyry is seen as a contact facies of a coarse porphyry similar to those observed east of the North fork and in the Rossland district, where the dykes are from the Rossland granite. So it would appear that the porphyry dykes of the Boundary district hold the same genetic relationship, although it has yet to be proved that they have no connection with the recent Tertiary volcanic rocks. Besides the porphyry dykes are others of dark lamprophyric rocks and some of a dark brownish basalt-like rock. On account of their somewhat limited occurrence and the lack of exposures at critical points, the relative age of these rocks with respect to that of the porphyries could not be determined, but from analogy of similar rocks in the Kootenay district one might expect them to prove to be newer.

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*Summary Reports, 1896 to 1900.

Volcanic rocks.

The recent volcanic rocks occur in numerous localities as outliers, remnants of a sheet of volcanic rocks which once covered the entire country, but which have been largely eroded away. The series consists of coarse and fine tuffs and ash beds, some shales and sandstones in which coal is found in places, sheets of andesites, basalts, pitchstone, and probably other volcanic rocks. These volcanic rocks often have phenocrysts of feldspar and are locally known as 'birds-eye porphyry.' Similar rocks have been found and described by Dr. Dawson in the country to the west and are largely represented in the areas embraced in his Kamloops and Shuswap sheets. From stratigraphical and fossil evidences he assigned them to the Tertiary. A few fossil plants, which have not yet been determined, were found in these rocks on the North fork of the Kettle river.

Distribution of the rocks between July creek and the North Fork.

Owing to the intrusive nature of most of the rocks, their distribution is complex and only a small area need be examined to form the acquaintance of most of the rocks of the district. Without going into details their occurrence is roughly as follows: In the country lying between North fork and July creek the rock is mainly greenstone, but with several important and many minor inclusions of sedimentary rocks. Of the latter, limestone, which is usually crystalline, is the most important. Near Badina Hill at the southern end of the ridge, is a thin bedded quartzite. Here also the limestone is replaced by silica forming a cherty quartzite-like rock. Dr. Dawson mentions a similar rock as characteristic of the Cache creek (Carboniferous) formation.

A belt of crystalline limestone is fairly persistent on the range near July creek, passing west of Eagle mountain, Hardy mountain and the head of Deer creek. Limestone is also exposed in Summit camp almost to Mineral Monument XVIII. The band is not wide, and owing to coverings of drift it is impossible to prove that it forms one continuous band. Smaller bands are found at various other points along the railway line on the North fork of the Kettle river, at the head of Lime creek, on the ridge between the B.C. mine and Rathmullen creek ahd other points. Argillites, more or less altered, occur in the greenstone on Hardy mountain, near the Majuba claim, and near them is a large mass of apparently very pure serpentine. To the north of these rocks is a 'stock' of the gray granite, very basic, holding inclusions of the greenstone and impregnating it.

Argillites.

Argillites occur near the mouth of Fisherman creek. They are black and in some parts appear to be highly carbonaceous. On the

Laurier claim, for example, is a prospect tunnel in a black coal-like rock, having the appearance in places of anthracite, but it is probable that it is highly silicious. On Hoffmann mountain, near the head of the East fork of July creek purplish argillites are caught up in the greenstone.

Volcanic rocks.

The summit of the range between Deer creek and Fisherman creek consists of the Tertiary volcanic series. Overlying the greenstone and associated rocks, are coarse and fine-grained tuffs, and above these are andesites and other volcanic rocks. The eastern portion of the range between Fisherman creek and Lime creek is also capped by this volcanic series. It extends southward almost to Fisherman creek. At their northern end, near Lime creek, these rocks are cut by a reddish porphyry, which becomes somewhat granitic in the centre of the mass. On the railroad, about a mile east of Eholt, is another exposure of the volcanic rocks. They extend north to Loon lake, westward to the hill across the B.C. wagon road, and east to about Rathmullen creek. On the railroad about a mile east from the edge of the volcanics are several large dykes of monzonite or essexite-like rock.

Rocks at Summit camp.

At Summit camp, on the Emma and Oro Denoro claims and extending north from the latter, is a small boss of gray granite. The hill to the north-east, on which is Mineral Monument XVIII., consists of a large basic dyke between limestone on the east and the greenstone on the west. It looks as if it might be a larger, coarser, more highly crystallized form of the dark basaltic dykes. The reddish and yellowish porphyry dykes are common about Summit camp, B.C. mine, Rathmullen, and other points where important mineralization has taken place. The basaltic dykes are frequently met with about Eagle mountain. Other dykes are found, but space can not be given for particulars regarding these in the present preliminary report. In the district between July and Boundary creeks the greenstone is still, perhaps, the dominant rock, but the areas of sedimentary rocks become more frequent and important, particularly on the Boundary creek slope, although they are still cut by and included in the eruptive rocks. Argillites, often highly altered, and the cherty altered limestone are common, but so mixed are the rocks in this area that it is impossible to give the occurrences of the rocks without going into a detailed description of the whole district.

Rocks between July and Boundary creeks.

Greenstones.

In Phœnix camp, north of the town, occur greenstones filled with inclusions, (or the greenstone tuff,) bands of limestone with some argillites, dykes of gray granite and porphyry. To the south of the town the greenstone and greenstone tuff is more massive, having fewer inclusions of the sedimentary rocks. Near the station and on the hill to the north-east, and on the ridge above the Gold Drift, the tertiary volcanic rocks overlie the older formation. In Wellington camp, on the Winnipeg claim and on the hill north-east, a mass of the gray granitic rock cuts up through the greenstone. A large inclusion of serpentine is also found here. On the wagon road toward the Athelstan claim a band of yellowish or brown weathering rock, locally known as dolomite is encountered, which extends through claims north-east and south-west. This rock, while made up of a certain amount of calcium and magnesium carbonates with some iron, is somewhat silicious and has probably been formed from serpentine. May creek and the head of McCarren creek are in massive greenstone.

In Central camp and on the ridge where No. 7 mine is situated, are considerable areas of more or less altered argillites. In Central camp serpentine is also largely represented. In places the latter is altered to a yellowish rock resembling that found near the Althelstan claim. Squeezed and altered dykes of granite porphyry are also common, together with masses of the monzonite-like rock. Similar mixtures of greenstone, argillites, limestone, serpentine, together with the numerous dykes are found on the slopes near Boundary creek. Around Midway, extending around the boundary line for a couple of miles, and northward across Norwegian creek to McCarren creek and west of Boundary creek to about Boundary falls is an important development of the Tertiary volcanic series.

Rocks on Boundary creek.

On Boundary creek, beginning at Anaconda and extending to the railway bridge above Greenwood is a mass of the gray granite. From Anaconda, the eastern boundary of the granite runs north-easterly to the Last Chance and Lake claims and then north-west to the mouth of Providence creek. The hills to the west of Boundary creek between these points are gray granite. This granite is found along the north side of Eholt creek to about Mile Post 84 on the railroad, and here greenstone reappears.

West of the North Fork between Brown's and Pass creeks the rock is essentially greenstone, but much cut up by porphyry and other dykes. From Pass creek north to a point opposite Rock Slide creek, the red granite obtains. Between this point and the forks of the river at Bunch Grass mountain, the west side of the river has not yet been examined. On the main North fork, above the forks of the East branch, gray granite predominates for the first six miles though extensively cut by pink acid granite and porphyry dykes from the red granite. Some red granite comes in above this point, but the main rock from here to the Coal Fields camp (about twenty-four miles by trail from Bunch Grass hill) is the pink acid granite. At the creek from the west, half a mile below Coal Fields camp, the Tertiary volcanic series comes in and extends to the camp. The rock exposed by the river cutting east of and opposite to the camp and for about one mile north is the acid micaceous granite. Here the volcanics are again exposed near the river for at least one mile. On the west bank of the river, the volcanic series, including the tuffs and shales, seems continuous. The main portion of the divide between the East Branch and the main North Fork is granite, and it is not probable that the area of Tertiary rocks will be found to have a strong development east of the main river nor for any great distance up the stream.

Glaciation.

None of the mountains in the area examined, are of sufficient altitude to support glaciers or snow-fields. But here, as elsewhere in Southern British Columbia, glacial phenomena due to the former Cordilleran glacier are everywhere strikingly evident. The rocks when protected from weathering are polished, striated and fluted. The average direction of striation, where uninfluenced by local causes is about S. 30° E. Transported boulders, often of large dimensions, occur scattered all over on the summits and ridges, as well as on the lower levels. Boulder clays are not common but re-sorted glacial material, such as silts and clays, is abundant. This drift material, when it occurs in a protected position, shows marked and persistent terracing. The terraces are very numerous, rising in tiers at intervals of from ten to one hundred feet to a height of about two thousand feet above the valleys. In the larger valleys, such as that of Boundary creek, the numerous terraces are a marked feature in the landscape. A detailed study of these terraces, with those already observed in West Kootenay and the Kamloops and Shuswap districts, would yield very interesting results. The glacial phenomena in this district are in accord with those observed in other portions of the west, once covered by the great Cordilleran ice-sheet.

Ore-bodies of Boundary creek district.

The ore-bodies of the Boundary district are, for the most part, large in size and low in grade. This is their striking characteristic. Development work has proved them to be much larger than at first supposed, and they have proved to be surprisingly well adapted for smelting, no fluxing or roasting being necessary, but on the other hand the values have proved lower than the assays from early samples had indicated. In many respects these ore-bodies resemble the ore-bodies of West Kootenay. They are in what are sometimes known as composite or shear zone veins, formed by mineralizing solutions traversing the country rock, principally along fissures or zones of fissures, in which they deposit the economic minerals, and from which they replace with their mineral contents, particle by particle, sometimes only partially, sometimes completely, the original material of the country rock.

Their form.

As might be inferred from their mode of formation, they resemble the West Kootenay bodies in being of irregular form, often with no well-defined walls. The country rock in the neighbourhood being mineralized to a greater or less distance from the ore body, the line between the two is often merely a commercial wall. As in the Kootenay the ore occurs in the veins in shoots of various forms. Sometimes several of these occur, often roughly parallel. Sometimes veins with similar filling cross one another at various angles, and small stringers leading from the main vein are of common occurrence. The intersection of veins, so far as observed, while sometimes increasing the size, has produced no marked enrichment in the ore body. The ore occurs in all rocks except the newest, the latter being the porphyry and basic dykes, the acid granite, the red granite and the Tertiary volcanic rocks.

Country-rock.

So far as yet found mineralization is confined to districts which show evidences of recent disturbance, especially where the older rocks are cut by the newer dykes. Limestone, in such a district, seems favourable for the deposition of ores. In some cases the ore occurs in the limestone itself, but more frequently it is found in a rock along its contact with limestone, which forms a clean-cut wall to the deposit. Thus in the greenstone, where the latter holds large inclusions of limestone, the ore occurs in the greenstone along its contact with the limestone, while the latter may show little or no mineralization.

Causes of mineralization.

The lack of mineralization of the limestone itself in such cases is due to the fact that under pressure the limestone, instead of fracturing, flows and forms lenticular masses, which furnish no channels for the mineralizing solutions. If attacked and replaced by them it must be along the contacts, and from the pureness of the limestone this will take place easily, leaving a clean-cut unmineralized wall. That the contacts between the limestone and other rocks should be favourable, may in part be due to the chemical influence of the limestone in precipitating the mineral contents of the mineralizing solutions, but it is also due to lack of firm cementing between the limestone and contact rock, thus leaving a free channel, which the solutions have used as a highway and basis for their operations. But while such contacts are favourable, mineralization is by no means confined to them, in fact in the largest deposit yet found in the district (Knob Hill, Ironsides), with the exception of an insignificant island of it in the intermediate level, limestone is conspicuously absent, although it occurs at numerous unmineralized points in this vicinity. While most of the deposits of ore are in greenstone, limestone, or in contacts between them, they also occur in the other older rocks, notably in the serpentine, argillites and gray granite.

Relationship between the dykes and ore-bodies.

The porphyry dykes which are associated with the ore-bodies, are usually to be found in close proximity to the ores, sometimes, as at the No. 7 mine, the ore occurs parallel to the dyke along the contact, or in the immediate neighbourhood. At the B. C. mine, Mother Lode mine and others, the dykes lie almost horizontal, running through the ore-body and intersecting it at right angles. The ore is found on both sides of the dykes, but, as far as known, it is not faulted by them, nor is the ore in any way altered by them, as might be expected if the dykes were newer and had been erupted through the ore, but in some cases the ore seems richer in the neighbourhood of the dykes.

That the dykes themselves show so little signs of mineralization and that the salband extends unbroken across the contact with the ore cannot be taken as proving that the dykes are subsequent to the ore formation, for the same phenomena are observable in West Kootenay where such dykes are known to be prior. If this is also the case in the Boundary district, the mineralization in such cases has taken place along fractured zones or fissures or contacts joining parallel dykes of porphyry. If mineralization has taken place in this way and a genetic relationship exists between the porphyry and ore (which in the Boundary district cannot be taken as yet proved) it would account for the enormous dimensions of the ore bodies. In the Mother Lode mine, where these conditions are found, development work, so far, has exposed an ore-body 1,180 feet long, 160 feet wide and 500 feet in depth.

Size of ore-bodies.

The Knob Hill-Ironsides lead, is of as yet unknown dimensions. It extends through the greater part of the length of both claims and probably into the Gray Eagles, the lowest slopes being 700 feet below the highest point of the vein, and diamond drilling has proved the vein to a depth of 800 feet. Its known width is said to be 400 feet. On the second level, three ore shoots are said to occur, one of 150 feet, one of 100 feet and a third of 200 feet in width. These with the mineralized rock between the shoots would make a total width of 800 feet. One stope, said to be 100 feet by 200 feet, is all in ore. While the above figures may be only approximately correct, they are sufficient to show the extent of mineralization. Some of the less developed properties also have very large ore-bodies. There has been considerable movement since the ore was deposited, numerous slips often with gangue or with secondary filling traverse the ore-bodies. This broken nature of the ground, coupled with the original irregularity in the form of the ore-body makes the exploitation of the smaller masses difficult and precarious. The slips so far encountered have not been sufficiently large to have seriously affected the greater ore bodies. The serpentine is particularly full of slips, some prior but many subsequent to the formation of the ore bodies, which make it probably the most unsatisfactory country rock in the district.

Mineral contents of the veins.

The mineral contents of the veins, arranged according to their prominence, are magnetite, pyrrhotite, chalcopyrite or marcasite, arsenopyrite, specularite (micaceous hematite); galena, zincblende and molybdenite occasionally occur, especially in the smaller veins. Tetrahedrite, ruby silver, argentite, native silver, native copper and the various oxydized copper minerals are reported from a few localities, for the most part in the smaller veins. When the ores consist largely of pyrrhotite and chalcopyrite they resemble some of the west Kootenay ores. The occurrence of large masses of magnetite in the ores is peculiar. It seems to take the place of the pyrrhotite, for so far as I could observe, where magnetite is prominent, pyrrhotite is absent, though in one or two cases it was present but only very sparingly. The pyrrhotite and magnetite appear to have been the first minerals of the ores to be deposited, though their period of formation extended into the period at which chalcopyrite and pyrite were formed. This is shown by the fact that while the latter are usually found as veinlets or small points or irregular masses scattered through this pyrrohotite and magnetite, they also occur in places interbanded with them.

Formation of magnetite.

The reason for the formation of magnetite in this manner would seem to be a deficiency in sulphur in the mineralizing solutions. That they were poor in sulphur is shown by the formation of pyrrhotite rather than a higher sulphide of iron. Where magnetite occurs they would appear to have been still poorer; the greater part of the iron could not obtain sulphur, all available sulphur being first seized upon by the copper, the remaining sulphur which the iron obtained being only sufficient to furnish the chalcopyrite. Oxygen would also be scarce, so hematite could not be formed and the iron appeared as magnetite. Later when the copper had been supplied the little iron remaining received enough sulphur to form pyrite. In some places the double sulphide of iron appears to be marcasite, being lighter in colour and more easily decomposed, leaving a cellular structure, but no crystals of marcasite have been seen. Arsenopyrite occurs only at one or two points, as in the Winnipeg and Morrison mines, and not in any great quantity. The specular iron which occurs in scales, often rosette in form, appears to be an oxydation product from the magnetite. It does not occur in very great quantity.

Gangue minerals.

Quartz and calcite are the common gangue minerals. Magnetite may often be considered to also play this role. Garnet, green and red (probably hessonite and almandine) and epidote, both well crystallized and massive, are very abundant in the veins often interbanded with the ores. They are probably largely alteration products of the country rock. This process can be observed at many points in all stages of development. The garnet and epidote are not confined to limestone, but are also abundant when greenstone and gray granite are the country rock. In the Mother Lode mine, where limestone seems to be the country rock, while these minerals are developed, the chief mass of the altered rock is made up of felt-like aggregates of short fibres, apparently actinolite. Silicification of the country rock to a cherty or quartzite-like material is a common phenomenon in the neighbourhood of a vein.

Values.

In the large deposits the values are principally in copper and gold with subordinate silver. In some of the small quartz veins carrying galena, zincblende, with tetrahedrite and silver minerals, silver is the principal value; in others, as No. 7, when pyrite likewise occurs, gold is also of economic importance, the galena and blende carrying silver and the pyrite gold. In the large deposits, further study is required in order to formulate the laws governing the distribution of the gold values. Generally the magnetite and pyrrhotite, when occurring alone, are almost barren of gold, but this is not always the case. On the Seattle claim the pure magnetite is said to carry good gold values. Specimens for assay have been taken to test this. What appears to be pure pyrrhotite in the Winnipeg carries as high gold values as have been obtained in the mine, but at other points in the same mine the pyrrhotite appears barren. As a general rule throughout the district the best values occur when the pyrrhotite or magnetite are mixed with chalcopyrite. An increase in the amount of copper seems occasionally to lessen the value of gold. This obtains in the Mother Lode, where about two per cent copper carries the highest gold values, but in the British Columbia mine on the other hand the values seem to be confined to the chalcopyrite; pyrrhotite and pyrite appearing to be almost barren. The chalcopyrite although segregated in places, is, on the whole, remarkably evenly distributed through the large ore bodies. Away from the chief centres of mineralization, although pyrrhotite or magnetite are sometimes found in considerable masses, gold and copper appear to be only sparingly present.

The actual value per ton and the cost of mining and smelting have not been made public.* The values are low, but the cost of smelting is also low and the management state that the mines are at present working on a paying basis. It is generally admitted, that many of the properties can only be worked profitably by mining companies owning smelters. For this reason a union of the smaller properties, or at least the building of a union smelter, is being agitated. The larger properties, such as Knob Hill, Ironsides and Mother Lode, are now mining by large quarries or 'Glory holes,' from which the material will be loaded directly into ore cars. On the Knob Hill, this will be done by a steam shovel. On the Mother Lode, the large blocks will be first put through a gigantic crusher capable of manipulating blocks a yard square and with a daily capacity of 800 tons. With this cheapening of the costs of mining and with double smelting capacity, which will be ready shortly, in both the Greenwood and Granby smelters, there should be an appreciable increase in the profits. The small quartz veins are said to yield high assays in places, but of these, the No. 7 vein was the only one being mined at the time of my visit. This ore probably runs from $12 to $15 per ton in gold and silver.

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* The Dominion Copper Company's ores yield a gross value of copper 1·95 % au. ·119 oz., ag. ·44, or a net value (with copper at 10 cts per lb.) of $5.72.

Lack of surface oxydation.

A striking feature of these deposits is the lack of surface oxidation. A few feet below the surface, the ore has the same character as exhibited in depth. The soil overlying the deposit is often quite unstained, affording no indication of the underlying deposit, and consequently adding to the difficulties of prospecting. Often the surface of ore even retains the glacial polishing. The explanation of this feature is probably to be found in the glaciation to which this region has been subjected. The old oxidized and probably enriched surface has been cut off by the Cordilleran glacier, and since glaciation, the surface has in great measure been protected.

Ores of Copper camp.

An apparently and at first sight different type of deposit occurs in Copper camp, of which the King Solomon affords the bsst example. This deposit is found at a contact between porphyry and crystalline limestone. Wedge-shape little tongues of the porphyry extend from the main dyke into the limestone. Both the limestone and the porphyry are much broken up and traversed by little slips. The fractures cut the limestone into little blocks. In the fractures in the limestone, and to a less extent in the fractures in the porphyry near the contact, are deposited various oxidation products of iron and copper and also native copper. These little blocks of limestone include red earthy hematite and yellow limonite, crystallized and massive malachite and azurite, a black amorphous substance probably a mixture of copper oxide and perhaps amorphous chalcosite, cuprite, often well crystallized in transparent crystals, native copper, chrysocolla, and the impure chrysocolla known as copper pitchblende. The edges of the little limestone blocks have often been dissolved and the copper ores then occur as encrustations surrounding a core of limestone. The main fissures are filled with the hematite and all the copper minerals; the smaller fractures principally with the copper. In the porphyry it is only the fractures which contain a thin film of the copper ores, the rock itself remaining fresh and unaltered.

Chemical changes.

About 650 feet north of the main working on the King Solomon is a small vein. The rock here is not so badly shattered. A few feet below the surface pyrite and chalcopyrite occur, although on the surface they have oxydized to sulphates and from the sulphates the green and blue carbonates of copper have been formed. What can be seen taking place on a small scale on this little vein is probably what occurred on the King Solomon ledge proper, on a much larger scale, so that the King Solomon is probably an oxydized and secondarily enriched form of a sulphide deposit similar to the other sulphide deposits of the Boundary district and due to oxydation and concentration by surface waters. The iron of the iron sulphides has been removed or left as red hematite or yellow limonite, the copper has been more or less concentrated as carbonates, oxides and native copper, probably black sulphide and other copper minerals. At a greater depth, the unaltered iron and copper sulphides will presumably be found, although between the oxydized minerals and unaltered sulphides it is quite probable that a zone of enriched sulphides will be met with. That this zone of oxydation and enrichment should be found in Copper camp and not in other parts of the district, is in part explained by the local topography and the broken nature of the country rock, but a cap of volcanic rocks which covers the hilltops all around and extends almost to the King Solomon ledge, has been, in all probability, a factor. This capping in glacial times is likely to have extended a little farther, in which case it would have protected the deposit from the scouring effects of the ice-sheet which has been shown above to have covered this area. Again the contact between these volcanic rocks and the older rocks is likely to be a natural water-way.

Some of the practical deductions from the study of the ore deposits may be summarized as follows:—

Practical deductions from a study of the deposits.

Since, with the exception of certain deposits in Copper camp there is no zone of oxydation and secondary enrichment in these deposits, no loss of values is to be expected in depth, while the present general conditions remain unchanged. On account of the irregular form of the ore-bodies and the complex nature of the rock-formation, a careful and detailed geological study of the ground in the neighbourhood of the mine would be of great practical value in the exploitation of the ore bodies.

For the same reason development work must always be kept well ahead of the actual mining. Crosscutting must frequently be done to determine the limits of the ore-body and to prove the existence or non-existence of parallel ore shoots. What appears a barren wall may often prove a barren zone between two ore shoots. The limits of the mineralization must be actually proved; and similarly only that ore can be reckoned on which has been actually blocked out.

Diamond drilling.

Diamond drilling can with advantage be used for prospecting and exploiting the ore-bodies. Magnetic surveys would also be of great value in locating them under the covering of drift, and also in testing for masses of ore in the mine workings themselves. Especially would this be the case in the magnetite deposits. In pyrrhotite deposits also, in other parts of the world, magnetic methods have proved successful. The pyrrhotite and magnetite should always be assayed, as barren looking material sometimes carries good pay values. The conditions where pay ore occurs, and the minerals in the ore should be carefully studied with the view of ascertaining which carry the values and what are the causes which produce the enrichment. The limestone contacts in mineralized districts should be carefully prospected. The limestone wall can often be used for following the ore, it being kept in mind that the ore does not always strictly follow the limestone contact, and that this rock may pinch out without causing the ore to likewise give out.

Districts which show evidences of disturbance through vulcanism manifested by heavy dyking are promising fields for prospecting. The porphyry dykes themselves may in places prove auriferous, as in twelve assays of porphyry dykes from West Kootenay, one-half yielded colours of gold. In a specimen of a dyke from Valkyr mountains examined last winter, free gold was visible even with the naked eye.

Mines at present working.

Besides ordinary prospecting, fourteen properties were being worked in the Boundary district at the end of the season, and of these ten were shipping ore. In Deadwood camp, the Mother Lode, Sunset and Morrison were working, the two former shipping ore. Some ore was also being shipped from the King Solomon in Copper camp, but work on the claim was at a standstill. In Greenwood camp, the Knob Hill Ironsides group was shipping heavily, and some work was being done on the Lake mine. The Brooklyn has just been closed down, in response to an order from head-quarters in Toronto, althongh the mine was reported to be looking promising. In Wellington camp, the Snowshoe was being developed and sending out small shipments. This was also the case with the Winnipeg. Work was also being resumed in the Golden Crown. The Athleston was closed down. In

Summit camp the B. C. was working and shipping, but the R. Bell, Rathmullen, Oro Denoro and other properties were closed down. On the North Fork of the Kettle river the Humming Bird was being worked on a lease and was making occasional shipments. The Jewel in Long Lake camp (which was not visited) was shipping. No. 7 mine in Attwood's camp was working and shipping. In Central camp the City of Paris, which shipped during the winter, was closed down, but it is expected that work will be resumed in the spring. Some development work was in progress at the Ruby in Smith's camp. In other parts of the district prospecting was being carried on. This is the case in the district south of Summit camp between July creek and the North Fork. In this area, while mineralization has taken place at a number of places, no large deposit of pay ore has as yet been encountered, although a fair showing of ore occurs on the Little Betts and Seattle claims.

As an indication of the progress of mining in the Boundary district the shipments of ore for the month of October might be quoted :—

	Tons
Old Ironsides and Knob Hill group	20,722
Mother Lode mine	8,730
B. C. mine	3,750
King Solmon	490
Snowshoe	330
Jewel	290
Winnipeg	190
No. 7	120
Sunset	50
Total	34,762

The total ore shipments for the year will approximate 385,000 tons.

Smelters.

The Granby smelter at Grand Forks has been working steadily since it was blown in a year ago. It has at present a daily capacity of about 670 tons. Two new furnaces to double its capacity are being added and are expected to be ready to blow in at the beginning of the new year. A converting plant to refine the math to blister copper was also being installed. With the completion of the railroad from Republic, Wash., it is expected that a large quantity of Republic ore will be treated at Grand Forks. The mines of the Granby Company at Phoenix can easily supply the enlarged smelter, as their output is practically limited only by the smelting facilities. The British Columbia Copper Co.'s smelter at Greenwood has also been running steadily with a daily output of about four hundred tons. Another furnace to double its capacity is also being installed. The Pyrite smelter at Boundary falls has remained idle since its completion.

North Fork coal.

Last summer a prospector, acting on information from the writer that Tertiary rocks occurring in the neighbourhood were likely to be coal-bearing, prospected new ground on the main branch of the North Fork of the Kettle river, which resulted in the locating of a small seam of coal. Following his lead a large number of claims have been staked, but of these only a limited number cover coal-bearing rocks, the remainder being in granite. The New Coal Fields, as they are locally called, are situated about twenty-four miles above the forks of the East Branch on the main North Fork of the Kettle river, or about fifty-two miles from Grand Forks. Here, as above mentioned, a Tertiary outlier lies on the granite. The Tertiary rocks consist of tuffs, ash rocks, and a little shale overlaid by basalts and other volcanic rocks. The first exposure of coal on the west bank of the river occurs in a coarse tuff filled with fragments of volcanic rocks, and crystals of minerals belonging to volcanic rocks. Above this tuff is a thick bed of another filled with boulders from the granite of the surrounding country. In the tuff are little lenses of carbonaceous material, the remains of plants of which the form is sometimes preserved, and a thin seam (about an inch) of argillaceous material and coal. The tuffs have been somewhat squeezed. The strike is about N. 20° E., angle of dip 45° W.

Wiseman's discovery.

About one mile and a quarter up the river on the east bank is Wiseman's discovery. Here a band of shale twelve feet thick lies between two big beds of tuff. Interbanded with the shale are one or two thin ash beds. The shales are exposed for about 200 feet along the river bank. Their strike is S. 19° to 34° W., dip 30° to 40° E. At the upper end of the exposure the shales are contorted, and at this point the coal is found. The pressure has broken the seam and probably increased its width. At the widest point it approximates one foot. Only about twelve feet of the seam are exposed, but as the upper end disappears under drift, nothing could be ascertained of its extension in that direction. The extent of coal-bearing rocks is not large as they are overlaid by the unproductive volcanic flows and immediately underlaid by granite which is exposed on the east bank for the greater part of the distance between the two exposures of coal. Nor have they a wide areal extension, as the granite boulders in the river and tributary creeks testify. All the divide between the main North Fork and the East Branch is granite. No work had been done on any of the claims at the time of visit, and the trail to the fields was not completed. This, coupled with bad weather and lack of provisions, prevented a careful examination of the whole Tertiary area.

Colonel N. E. Linsley, of Spokane, who examined the district after my visit, reports having discovered four seams of coal on the lower (Gilpin's) claim. Of these, the upper (seven inches wide) was the largest and was separated from the lowest by 150 feet of tuffs. He also found the area of coal bearing rock to be extremely circumscribed. The coal is of very fair quality, coking easily and well.

Possibility of the occurrence of platinum.

The recent increase in the use of platinum has created a strong demand for this metal, and it is now as valuable as gold. Its principal source is in alluvial sands where it occurs with garnet, magnetite and gold and other heavy minerals. As sand, it is sometimes very fine and of a brown or lead color. Treated with nitric acid it shows a white colour. It has been found in the Similkameen district and is known to occur at many points in the Western States. When found in place it has been principally confined to serpentine, and when found in sands it is usually in the neighborhood of serpentine. Consequently streams draining masses of serpentine, in particular should be prospected for platinum. Serpentine, as above noted, occurs at a number of points in the district examined this summer, as on July Creek, Hardy Mountain and Central Camp. It also occurs on the range east of Cascade.

In conclusion I wish to thank the mine managers one and all for their unfailing courtesy, attention and assistance.

CROWS NEST COAL FIELDS.

Mr. W. W. Leach.

Work by Mr. W. W. Leach.

On June 3, I left Ottawa with instructions to continue the examination of the Crow's Nest Pass Coal-fields, begun by Mr. McEvoy last year. Mr. T. C. Denis, B.A.Sc., accompanied me during the season. I returned to Ottawa on October 24.

Assistance by Mr. McEvoy.

On arriving at Fernie, some days were spent in becoming acquainted with the Cretaceous coal-bearing rocks of that neighbourhood. Mr. McEvoy, formerly of this department and now with the Crows Nest Pass Coal Company, very kindly accompanied us on several expeditions into the surrounding hills, assisting us very materially with his knowledge of these rocks, gained during the previous season.

On June 15, instructions were received to examine immediately two reported outlying coal areas, separate from the main or Crows Nest area, or such parts of them, that, being included in the lands earned by the Canadian Pacific Railway Company, might be taken into account when the selection of Government coal lands was made.

Of these two areas, the Northern or Green hills area was mentioned by Dr. Dawson in his report on 'that portion of the Rocky Mountains between latitudes 49° and 51° 30′ (see Annual Report, 1885, vol. I., page 109 B.); while the southern one was reported to Mr. McEvoy last year by Mr. Phillips of Tobacco Plains. It was considered advisable to examine the Northern area first, it being the more easy of access at that early season. Considerable difficulty was experienced in reaching the field of operations; the trail, following the valley of the Elk river, then in flood, being under water in many places.

This area is situated on the east side of the Elk river, the southern edge of it being about twenty-four miles above the mouth of Michel creek. It extends northwards an unknown distance.

Green Hills coal area.

Generally speaking the attitude of the Cretaceous rocks of this locality is that of a wide, flat syncline, the upturned edges resting conformably on the flanks of two high limestone ranges of Devono-Carboniferous age, one on the west side of the Elk river and the other on the east side of Fording river.

In that part of the area examined, the upper beds of the Cretaceous rocks, represented in the Crows Nest area by coarse sandstones, conglomerates and brownish and yellowish shales, have been entirely eroded away and with them some of the coal measures, but further to the north it is probable that these upper beds will be represented at least partially. The coal-bearing lands, within the boundaries of lot 4,588, group I., (the property of the Canadian Pacific Railway Company), are, roughly speaking, of triangular shape, about 4½ miles in length and 1½ miles in average width, with the apex of the triangle to the south, and occupy the summits of the Green hills, which form the watershed between the Elk river to the west and Fording river to the east. Fording river being a tributary to Elk river, with a course approximately parallel to it. The general direction of the summits of these hills being about N. 20 W., with a maximum elevation of about 7,200 feet.

Coal seams.

The coal seams noted, twelve in number, outcrop along the crest of the ridge. The lowest one seen coming to the surface, just south of the most southerly point of the ridge, striking here nearly east-and-west and dipping at about 60° north. From this point northwards, in a distance of about 1½ miles, the strike gradually swings round to about N. 30 W., with a dip of 26° N.E. This strike and dip remains fairly constant as far northward as was noted.

An attempt was made to measure a section across the coal measures, but, as the time was limited and the rocks much covered, it must be considered as open to revision on more detailed work. The result attained is as follows, given in descending order:

	Feet.	Section.
1. Sandstone	103·0	
2. Shale	67·0	
3. Coal	4·5	
4. Shale	5·0	
5. Sandstone	55·0	
6. Shale	8·0	
7. Coal	1·75	
8. Shale	5·0	
9. Coal	35·5	
10. Black shale	5·0	
11. Sandstone	46·0	
12. Shale	24·0	
13. Arenaceous shale	35·0	
14. Coal	3·0	
15. Shale	7·0	
16. Sandstone	18·0	
17. Coal	0·75	
18. Shale	42·0	
19. Sandstone and arenaceous shale	54·0	
20. Coal	7·0	
21. Sandstone	114·0	
22. Covered	365·0	
23. Shale, sandstone and covered	261·0	
24. Sandstone	7·0	
25. Coal	2·5	
26. Shale	15·0	
27. Coal	8·0	
28. Shale	158·0	
29. Coal	8·0	
30. Covered with shale outcrops	300·0	
31. Black shale	40·0	
32. Shale and thin bed of sandstone	275·0	
33. Covered	1,010·0	
34. Shale	15·0	
35. Coal	2·5	
36. Shale	23·0	
37. Coal	8·0	
38. Shale	10·0	
39. Covered	210·0	
40. Coal	8·0	
41. Shale	20·0	
42. Sandstone		
Total	3,386·5	
" thickness of coal	89·5	

It is quite probable that there are other seams which were not seen, and it is also possible that some of the seams may appear twice, as the measurements were not continuous, but an attempt at compilation of several partial sections. Immediately below the base of the section the ground is heavily drift-covered with a few exposures of hard gray sandstone, leaving room for other seams.

Beds underlying coal measures.

The lower beds of the Cretaceous rocks in this neighbourhood show a wide variation from those noted by Mr. McEvoy in his section measured last season near Morrissey, whereas he shows these beds to consist of black and brownish shales, sandy argillites, shaly limestone and calcareous shales (see Summary Report, 1900, page 89), here they are composed almost entirely of hard, light-coloured, rather fine-grained sandstones with a few thin beds of gray shale. The rocks included in the coal measures consist principally of black and gray shales, dark-coloured sandstones and a few thin beds of impure dolomite.

Faulting.

On the east side the coal measures are cut off by an overthrust fault of large dimensions, the line of faulting being nearly parallel to the axis of the ridge, the upper beds of the Devono-Carboniferous limestones and quartzites being lifted to the surface and having the appearance of overlying the coal-measures. Crossing these limestones and quartzites in a northeasterly direction the lower Cretaceous beds (sandstones) are again encountered overlying conformably the Carboniferous rocks. These continue across the valley of Fording river, still dipping to the north-east at decreasing angles, till the coal measures are again met with on the eastern slope of a line of hills which lie between Fording river and the main limestone range to the east. The summits of these hills conforming approximately to the axis of the syncline of the Cretaceous basin. Besides this large fault there are evidences of a number of minor disturbances, but the limited time at our disposal made it impossible to trace them out in detail.

Quality of coal.

No analyses have been made of any of the coal from this area, but in general appearance it is very similar to the coal from the Crows Nest area. The quality of the coal in the various seams does not seem to differ to any great extent, though it is probable that the seams numbered 27 and 29, in the above section, contain a slightly better quality of coal than the remainder. This area is, at present, very difficult of access, but the Elk river valley presents an easy route for a railway from the Crows Nest Branch of the Canadian Pacific railway at the junction of Michel creek and Elk river to the base of the Green hills. That part of the coal area visited, however, is situated at an elevation varying from 2,800 feet above the valley of the Elk at its southern extremity, to about 2,000 feet above the valley at the northern boundary of lot 4,588, group I, the slope from the valley to the summit of the ridge being very steep. Within these limits there are no transverse valleys of sufficient size to afford a practicable grade from the Elk valley to the coal measures. It is probable, however, that further to

Means of access.

the north the coal measures outcrop in the valley of Elk river and may *possibly* cross it to the west side.

A rough topographical survey was made of the southern part of this area, a base line having been measured with the Rochon micrometer, angles read with prismatic compass and elevations with the aneroid barometer.

Timber.

The greater part of the timber in this part of the Elk valley has been destroyed by fire, though patches of good spruce (*Picea Engelmanni*) and tamarack (*Larix occidentalis*) remain.

Sulphur spring.

There is a remarkable sulphur spring on the Elk river trail about 17 miles above the mouth of Michel creek. The river valley here is rather wide, open and prairie-like. This spring is situated immediately at the foot of the eastern slope, and occupies a basin about 75 feet long, 40 feet wide and 9 feet deep. The water is strongly impregnated with sulphuretted hydrogen gas, which bubbles up from the bottom in four or five places; the characteristic odour of the gas is noticable for upwards of a mile from the spring when the wind is from that direction. The water is warm and beautifully clear and of a bright green colour. An analysis made by Dr. Hoffmann, of specimens from the deposit at the discharge of this spring gave the following results: 'A mixture of carbonate of lime, with a small quantity of sulphate of lime, a very little earbonate of magnesia and a small quantity of free sulphur.'

Reported southern coal area.

On returning to Fernie, preparations were made to leave for the Wigwam river, where the southern coal area was supposed to be situated. Leaving Fernie on July 16 we travelled down the Elk river to the Kootenay valley, thence south to the Tobacco Plains, where I interviewed Mr. Phillips, who, as before stated, had first mentioned the existence of this supposed southern coal area to Mr. McEvoy. Having been furnished by him with a sketch-map of the district, we returned northwards about twelve miles to Desrosier's, where the trail for the Wigwam river leaves the main road. This trail, following an easterly course, crosses the Galton range, which separates the Kootenay river from the Wigwam, at an elevation of about 6,100 feet, coming down to the Wigwam river about twelve miles above its mouth. Crossing the river here, we ascended Bighorn creek, a large tributary from the east, camping about four miles up this stream. Some days were spent here examining the rocks in the vicinity. These consisted chiefly of quartzites with some dark quartzose argillites and micaceous schists. Similar rocks had been crossed all

Rocks of Bighorn creek.

the way from Desrosier's to the Wigwam river, referred to by Dr. Dawson as the 'Quartzite Series' of Cambrian age.*

The attitude of the Cambrian strata is here considerably disturbed, the axes of the folds being, generally speaking, along north-and-south lines. These rocks are overlain by a great thickness of limestones of Devono-Carboniferous age, which were also met with on Bighorn creek, about half a mile east of our camp and they apparently extend eastwards to the head of the creek, forming the backbone of the Macdonald range, a high and extremely rugged group of mountains which forms the divide between the Flathead and Wigwam rivers.

Return to Tobacco Plains.

Being satisfied that there were no coal-bearing rocks in the basin of Bighorn creek, I returned to Tobacco Plains to obtain, if possible, further information, Mr. Denis remaining at Bighorn creek continuing the topographical work of that neighbourhood. On arriving at Tobacco Plains, I visited Mr. Phillips again. He stated that coal existed further up the Wigwam river, near the international boundary, and offered to send his son with us to point out the locality. The following day I started back for Bighorn creek with the understanding that Mr. Phillips, jr., would overtake us before evening. However, he did not put in an appearance; so, after waiting two days at our old camp on Bighorn creek, it was decided to move on up the Wigwam without him. This river here flows nearly due north and occupies a rather wide, flat-bottomed valley. There being no trail, progress was necessarily slow, but advantage was taken of the low state of the water, which enabled us to keep in the river bottom, crossing and recrossing from one bar to another, except in places where the valley narrowed to a gorge, compelling us to cut a trail on the hillside. In this manner the river was ascended to the international boundary.

Ascent of Wigwam river.

Camps were made at several points in the valley and from them the country was explored on either side, but nowhere were any Cretaceous rocks found, the hills on both sides being composed of Cambrian strata, chiefly quartzites. Time was not available to make any complete section of these rocks, the structure generally being somewhat complicated with evidences of much faulting and folding. The upper beds are composed chiefly of rather thin-bedded white quartzites. These are underlain by altered greenish and grayish argillites, usually highly siliceous, some thin beds of gritty silicified sandstone followed by massive red quartzite and impure dolomitic limestones. Near the summit of the Galton range, about five miles north of the boundary, a very hard dark-green intrusive rock was seen cutting the Cambrian strata; this was the only intrusive rock noted in place, though in the drift of the river and its tributaries in the vicinity of the boundary there were many fragments of a dark very hard amygdaloidal trap. These Cambrian rocks extend from the river westwards at least to the summits of the Galton range and eastward about five miles, when the Devono-Carboniferous limestones of the Macdonald range are found overlying them.

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*See Annual Report, Geol. Surv., Can., 1885, (N.S)., vol. I, page 78B.

The ground covered, included practically all of the Wigwam basin, from the mouth of Bighorn creek to the international boundary, and within these limits it is fairly certain that no coal-bearing rocks exist. A few days before returning to Ottawa, however, I was informed that coal was reported to have been found between the head of the Wigwam river and Tobacco Plains on the west slope of the Galton range. If there is any truth in this report, the area must be very limited in extent.

Timber.

The valley of the Wigwam river is well wooded throughout with timber of fair size; spruce, (*Picea Engalmanni*), and black pine, (*Pinus Murrayana*) being the predominant trees of the lower levels, while on the higher ridges *Pinus Albicaulus* and *Abies Subalpina* are most abundant.

Game.

Deer are very plentiful, and this valley appears to be one of the few remaining places in this part of British Columbia where beaver are to be found in any numbers.

As the object of our exploration was to search for coal, any detailed topographical work was not attempted, but enough was done to compile a preliminary map of this section.

Arrival of Mr. Pearce.

When we returned to Fernie on August 17th instructions were received to await Mr. Wm. Pearce and co-operate with him in the selection of coal lands that he was to make for the Government. In the meanwhile a few days were spent in preparing a sketch-map and short report of the Green Hills area. Mr. Pearce arrived on the 21st and until August 27th we were engaged with him in examining the various openings that had been made on the coal seams of the Crows Nest Coal Field.

A trip was then made to Marten creek and the South Fork of Michel creek with the intention of defining the eastern outcrop of the coal measures, but work had hardly been begun there when a message was received from Mr. Pearce, requesting us to return to Fernie to meet Messrs. Taylor and Turriff who had arrived there from Ottawa to undertake with him the selection of the Government coal lands.

About ten days were occupied in going over the ground with these gentlemen, after which we returned to Marten creek. The lateness of the season with the presence of snow prevented us from continuing our work in the higher mountains, so the remainder of our time was spent in measuring a section of the coal measures on this, the easterly outcrop of the basin as well as examining the upper valley of the South fork of Michel creek with reference to its suitability as a site for mining operations.

Localities suitable for mining operations.

Mr. McEvoy, in his report of last year, mentions five localities from which the coal measures are easy of access, two of these, Michel and Coal creeks, as well as the north side of Morrissey creek are already occupied by the Coal Company, while on the south side of Morrissey creek some prospecting has been done by the Canadian Pacific Railway Company. No important development work has as yet been done at either of the remaining localities—Lodgepole creek and the South Fork of Michel creek. The first of these was visited by Mr. Pearce, while we directed our attention to the latter.

South fork of Michel creek.

The coal measures outcrop in the valley of the South fork of Michel creek, at a point about 10½ miles above the 'loop' of the Crows Nest Branch of the Canadian Pacific Railway, and at an elevation of about 900 feet above the railway. This valley would thus afford a comparatively easy grade for a branch line, and, as it is fairly wide and flat-bottomed, there would be ample room for coke ovens and other necessary structures. As stated by Mr. McEvoy, there are two faults running parallel to the valley, one on each side; the eastern being the most important. This fault was not traced northwards farther than the branching forks of the South fork. To the south, it continues nearly parallel to the stream about a mile to the eastward, to near the summit, when the valley swings round to the east, meeting the line of fault which continues across the summit and down the valley of a branch of the Flathead river. This fault is probably an overthrust from the east, the rocks to the west of it in the valley being chiefly conglomerate and gritty sandstones with some beds of brownish and yellowish arenaceous shales, characteristic of the beds overlying the coal measures.

Western fault.

The western fault lies generally below the outcrop of the coal seams on the face of the escarpment, and dies out about one mile and a half south of Marten creek. The structure here is difficult to trace out as the hillsides are heavily drift-covered and densely timbered, exposures being very scarce. However, it is possible that this is also an overthrust fault, the movement in this case being from the west. If so, the area lying between these two faults in the valley-bottom must be underlain by the coal measures, but further information is necessary before the attitude of these beds is made entirely clear.

The section given below was measured at a point on the west side of the creek, about two miles and a half south of the mouth of Marten creek. The lower seams are not included, as they outcrop in the valley-bottom where the covering of drift is so deep that it was impossible to uncover them in the time available. The strike here is generally about N. 9° W., dip about 25° to the west, gradually flattening towards the west. This dip remains fairly regular to the north for about a mile, when the western fault mentioned above is met with. To the south the coal seams gradually disappear beneath the bed of the creek, which is here rising rather rapidly, till the summit is reached, when they are cut off by the eastern fault and do not outcrop again for some miles down the Flathead river.

The section which follows, measured by Mr. Denis, is given in descending order :

Measured section.

		Feet.
1.	Gray arenaceous shale with occasional narrow bands of black shale	46·2
2.	Sandstone	61·5
3.	Gray shale	24·9
4.	Coal	4·2
5.	Gray shale	30·0
6.	Black shale	3·2
7.	Coal	2·8
8.	Black shale	3·2
9.	Gray shale with narrow bands of black shale	89·3
10.	„ „	9·2
11.	Black „	10·0
12.	Sandstone	0·7
13.	Gray and black shale	8·4
14.	„ shale	47·5
15.	Coal	2·0
16.	Gray shale with narrow bands of carbonaceous shale	5·7
17.	„	82·7
18.	Coal with shale parting	3·6
19.	Gray shale	9·4
20.	Black „	3·0
21.	Gray „	7·7
22.	Coal	0·8
23.	Gray shale	64·7
24.	Coal with shale parting	7·3
25.	Gray and black shale with a little coal	8·7
26.	„ shale	25·0
27.	Coal	1·5
28.	Black shale	4·6
29.	Gray „	7·2
30.	Coal	13·0
31.	Black shale	0·8

32.	Arenaceous shale with thin beds of sandstone	31·0
33.	Gray shale with a little coal	73·5
34.	Carbonaceous shale and coal	1·6
35.	Gray shale	8·2
36.	Coal	2·1
37.	Shale	16·1
38.	Covered	32·0
39.	Sandstone	8·2
40.	Arenaceous shale with narrow bands of black and carbonaceous shale	32·0
41.	Black and carbonaceous shale with thin seams of coal	24·4
42.	Coal with shale parting	7·1
43.	Black shale with thin seams of coal	46·1
44.	Dark grayish shale	15·6
45.	Coal with shale parting	25·2
46.	Black shale with thin seams of coal	10·0
	Total	921·8
	" thickness of coal	69·6

A comparison of this section with that measured by Mr. McEvoy last year near Morrissey, gives the following results :—

Correlation with section near Morrissey.

On South Fork of Michel Creek.		*Near Morrissey.*	
Seams numbered.	Feet.	Seams numbered.	Feet.
24 Coal with partings	7·3	50 Coal	7·0
Intervening beds	47·0	Intervening beds	35·0
30 Coal	13·0	53 and 55 Coal with parting	14·0
Intervening beds	115·1	Intervening beds	154·0
36 Coal	2·1	58 Coal	3·0
Intervening beds	112·7	Intervening beds	120·0
42 Coal with partings	7·1	61 Coal	10·0
Intervening beds	61·7	Intervening beds	140·0
45 Coal with partings	25·2	63 Coal (upper 10 feet impure)	36·0

It will be seen from the above table that the coal seams are fairly persistent, considering the fact that these two points are about ten miles apart. The intervening beds, however, show a wider variation with a decided tendency to thin out in the lower part of the section at least.

The Crows Nest Pass Coal Company are operating mines at three points, Michel, Coal creek and Morrissey creek. At present Coal creek is their principal point of supply, producing over 1,600 tons a day. During the past summer extensive improvements have been made and new machinery installed, two Robb engines of 250 horse power each, one 200 horse-power compressor, and a new ventilating fan with a capacity of 250,000 cubic feet of air per minute, as well as a new tipple for the No. 1 mine having been added to the plant at Coal creek. With these additions in operation it is expected that the output will be very largely increased before long.

Mining operations.

At Michel the output has been about 200 tons a day, won chiefly in the course of development work. Mining at this point is attended with more difficulties than at either Coal or Morrissey creeks, several faults having been encountered, the structure generally being more disturbed, and the coal more sheared and friable.

Railway construction.

No shipments have been made as yet from Morrissey but preparations are well under way and it is expected that before long the output from this point will equal or even exceed that from Coal creek. A spur line is now nearing completion from the Crows Nest Southern Railway to these mines. This railway, at present under construction, runs from Fernie to Tobacco Plains, there connecting with the Great Northern Railway, and will afford an outlet to the south for a large output of coal. Six seams have been opened up at Morrissey which correspond to seams numbered 61, 63, 71, 73, 75 and 81 in Mr. McEvoy's section (see Summary, 1900).

The Crows Nest Pass Coal Company have now in operation at Fernie 424 coke ovens, of which 112 have been built during the past summer, producing about 850 tons of coke a day. At Michel, a battery of 212 ovens is now under construction, while at Morrissey the company is contemplating building 50 more.

Prospecting by C.P.R.

As before mentioned, the Canadian Pacific Railway Company has done some prospecting work on the south side of Morrissey creek. In addition to this, some work has been done by this company on the South fork of Michel creek, several seams having been uncovered here. In most cases, however, sufficient work was not done to show the thickness of the seams and, on account of the disconnected nature of the work, the relationship of the seams in the various openings was not clearly shown. Two bore holes were sunk with a diamond drill by this company near Michel, both immediately alongside the railway, the first (No. 1) about 1·4 miles, and the second (No. 2) about 2 miles south-east of the station. Copies of the records of these borings, kindly furnished by the company, are given below.

Drill holes at Michel.

No. 1 Drill Hole.

		Feet.	In.
1	Sand and gravel	7	6
2	Hard gray sandstone	41	6
3	Conglomerate	23	0
4	Hard sandrock and conglomerate	16	0
5	Soft black sand	2	0
6	Slate	21	6
7	Coal and slate	1	6
8	Coal	3	0
9	Slate	15	0
10	Coal	3	

		Feet.	In.
11	Slate	15	0
12	Sand shale	26	6
13	Coal	0	6
14	Soft black slate	1	6
15	Coal	2	0
16	Sand shale	73	6
17	Coal	5	0
18	Coal and slate	20	6
19	Sand shale	22	6
20	Gray sandrock	20	0
21	Slate	13	6
22	Coal	3	9
23	Soft slate	0	9
24	Coal	2	3
25	Soft slate	1	0
26	Coal	3	3
27	Soft slate	0	9
28	Coal	1	3
29	Soft slate	1	0
30	Coal	2	0
31	Soft slate	0	9
32	Coal	2	0
33	Slate	6	6
34	Coal	7	0
35	Sand shale	10	0
36	Dark hard sandstone	94	0
37	Coal	4	0
38	Slate and coal	2	0
39	Sand shale	13	0
40	Black slate	25	9
41	Coal	5	6
42	Slate and coal	4	9
43	Sand shale	11	0
	Total	536	0

No. 2 Drill Hole.

		Feet.	In.
1	Sand and gravel	6	0
2	Gray sandrock	75	0
3	Gray sandrock and conglomerate	12	0
4	Slate	18	6
5	Coal	2	6
6	Slate	18	0
7	Slate and coal	1	0
8	Coal	5	0
9	Slate and coal	3	0
10	Slate	7	0
11	Coal	2	0
12	Slate	23	0
13	Shale	119	0
14	Dark gray sandrock	23	0
15	Slate and coal	10	0
16	Coal	8	0

Section.

		Feet.	In.
17	Slate	0	6
18	Coal	0	6
19	Slate	0	3
20	Coal	7	3
21	Slate	1	3
22	Coal	0	6
23	Slate	7	6
24	Coal	8	9
25	Slate	0	9
26	Coal	6	3
27	Slate	0	9
28	Coal	0	6
29	Slate and coal	5	9
30	Coal	2	0
31	Sand shale	10	0
32	Dark gray sandrock	58	0
33	Black slate	10	3
34	Coal	2	6
35	Sand rock, shale and slate	39	9
36	Slate and coal	1	0
37	Hard gray sandrock	13	0
	Total	510	0

It will be noticed that there is no mention of the dip of the strata in either case, so that it is probable that a deduction from the above figures should be made, as it is not likely that the strata here are horizontal. It is evident that the sections shown by these two bore holes are at the same horizon, although the coal seams show a wide variation in the two holes, one seam, No. 17, shown in bore hole No. 1, not appearing in No. 2 hole. This may be due to local thinning out. These sections hardly afford sufficient information to attempt a correlation with Mr. McEvoy's section near Morrissey. It is possible, however, that the seams from Nos. 22 to 34 in bore hole No. 1 and from Nos. 16 to 30 in bore hole No. 2 represent the seams included between Nos. 77 and 81 in the Morrissey section.

Fossils.

The following fossils were collected during the summer, both from the coal-bearing rocks and the underlying limestone, all of them, as yet, being undetermined: Seven fragments of belemnites and one impression of an ammonite from the shales underlying the coal measures near Fernie; one fossil plant from lower shales at Hosmer, two fossil plants from coal seams at Morrissey, eighteen fossil plants from coal seams at Green Hills, four corals and several spirifers from top of Devono-Carboniferous limestones of the Green Hills.

RED DEER RIVER, ALBERTA.

Mr. Lawrence M. Lambe.

The second part of 'A Revision of the Genera and Species of Canadian Palæozoic Corals' was issued early in May. This report, referred to in last year's Summary as being then in the press, forms part II of volume IV of 'Contributions to Canadian Palæontology' and is descriptive of the Madreporaria Aporosa and the Madreporaria Rugosa. The two parts of this report on fossil corals together comprise two hundred pages of text illustrated by eighteen plates.

Cretaceous vertebrates.

The study of the vertebrate remains from the Laramie and Belly river series of the Cretaceous of the North-west Territories was continued during the past year, and considerable progress has been made therein, the object in view being the production of an illustrated report, descriptive principally of the Dinosaurian, Chelonian and Crocodilian remains found so admirably preserved at many localities in our North-west. The material available for study consists, for the most part, of collections made by myself on the Red Deer river, Alberta, in 1897 and 1898, to which has been now added a large collection made during the past summer in the same locality. Additional to these collections are specimens previously obtained from the same horizons, at a number of localities in the North-west, by officers of the Survey, viz: by Dr. G. M. Dawson in 1873, 1874 and 1881; by Professor John Macoun in 1880, by Mr. R. G. McConnell in 1882, by Mr. T. C. Weston in 1883, 1884 and 1889 and by Mr. J. B. Tyrrell in 1884.

Collection of Dinosauria.

Over two months, viz., July, August and part of September were spent in the field this year. Acting under instructions to supplement the collections of 1897 and 1898, by spending another season in the Red Deer river district, I left Ottawa on July 2 and proceeded direct to Medicine Hat, Assiniboia, where provisions, etc., were procured. The Red Deer river was reached by trail from Bantry, a flag station on the Canadian Pacific Railway, about sixty-five miles north-west of Medecine-Hat.

Field-work.

In the extensive area of 'bad-lands,' exposing the rocks of the Belly river series of the Cretaceous, on the Red Deer river between the mouth of Berry creek and Dead Lodge canyon, where I remained in camp until the end of the first week in September, I was successful in securing a large collection of Chelonian, Dinosaurian, Crocodilian, fish, primitive mammalian and other vertebrate remains of considerable scientific value. This collection is of importance in working out the material already on hand, as it throws much additional light on some of the problems relating to the generic and specific affinities of the animals represented in the collections of former years. It also adds to our knowledge of Cretaceous vertebrate life generally, indicating at the same time the richness of the palæontological field in the north-west and the possibilities there for further research.

Importance of collection of 1901.

I was assisted in the field by Mr. Heber Cole, of Montreal, who contributed materially in every way to the success of the expedition. After returning from the west, until the end of the year, my time was almost entirely occupied in a preliminary study of the newly acquired material from the Red Deer river.

A short paper on *Adocus variolosus*, Cope (sp.), one of the turtles represented in the collections from the Red Deer river, was issued in June last. This report appeared in the 'Ottawa Naturalist' under the title 'Notes on a turtle from the Cretaceous rocks of Alberta' and is illustrated by four plates.

Cretaceous turtle.

The following notes are descriptive of some interesting turtle remains collected last summer :—

ON TRIONYX FOVEATUS, LEIDY, AND TRIONYX VAGANS, COPE, FROM THE CRETACEOUS ROCKS OF ALBERTA.

By Lawrence M. Lambe.

(With four plates.)

During the past summer whilst engaged, on behalf of the Geological Survey, in making a collection of vertebrate remains from the Cretaceous of the Red Deer river, Alberta, to supplement the material obtained in two former years, the writer was fortunate enough to secure two almost complete carapaces of turtles, one referable to *Trionyx foveatus*, Leidy, the other to *T. vagans*, Cope. In the Red Deer river district, referred to, the remains of these two species are abundant and are found associated with a number of other species of Chelonia, of which one is *Adocus variolosus*,* Cope (sp.), remarkable alike for its size and the strikingly rugose character of the sculpture of its shell. The rocks holding these remains belong to the Belly river series of the Cretaceous brackish water deposits underlying the Pierre Fox-Hills formation, by which they are separated from the still higher Laramie series.

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*Proceedings of the Academy of Natural Sciences of Philadelphia, vol. XXVIII, p. 257, 1876 (Cope), and Ottawa Naturalist, vol. XV, p. 63, plates iii, iv, v and vi (Lambe).

Trionyx foveatus[†] was originally described in 1860 by Leidy from small fragments of costal and sternal bones from the Judith river beds of Nebraska.

The Red Deer river specimen of *T. foveatus* consists of the carapace, in which the nuchal plate is missing, without any part of the plastron. Sternal plates, probably referable to this species, were found not far distant, but further reference will not be made to them here.

The carapace (Plate II, fig. 2) is a little less than one-fourth broader than long, and is only slightly convex. The eight costals of the left side are practically entire, but the first right costal is wanting. Five neural plates are preserved with part of another that lay principally between the first costals, its posterior end being between the front inner borders of the second costals. If this neural were as long in proportion to its breadth as the plate immediately following it, its front margin probably effected a sutural union with the nuchal plate, and its outline was presumably as is shown by the dotted lines in the figure.[‡] Neurals two, three and four are six-sided, neural five is oblong, and neural six, lying for the most part between the sixth costals, is shield-shaped, coming to a point behind. The seventh costals are suturally united at their inner ends, where they develop a breadth sufficient to separate the eighth costals from each other. These latter are subtriangular in shape, with three convex sides. The nuchal plate was evidently small, as the lateral termination of the suture (*a* in the figure) between it and the left first costal indicates a side extension scarcely past a point in advance of the mid-length of the first costal. Small, shallow, rounded depressions mark the surface of the neurals and the inner ends of the costals. In the latter, as the distance from the neurals increases, the depressions gradually grow larger and more decided, becoming often reniform or oval, and frequently coalescing, until in the distal ends of the costals a few more or less continuous furrows are formed parallel with the outer margins of the plates. These furrows are a conspicuous feature in the sculpture; they are not so well marked on the posterior margin of the carapace, but they are well developed near the front edges of the first costals. In the neurals and inner halves of the costals there is a narrow, smooth strip devoid of sculpture bordering the sutures. The rib-heads are well developed.

[†] Transactions of the American Philosophical Society, vol. XI, p. 148, pl. xi, figs. 1 and 2. Extinct Vertebrata from the Judith river and Great Lignite formations of Nebraska.

[‡] Since the above was written some misplaced fragments have been added to the anterior end of this carapace; they reveal the fact that the first costals are in reality separated by a divided first neural. The writer wishes here to express his indebtedness to Professor Osborn and Dr. Hay, of the American Museum of Natural History, for the loan of the type of *Trionyx vagans* and the opportunity thus afforded him of making a direct comparison of the type with the Red Deer specimen.

Measurements :

	M.
Estimated length of carapace along median line ($6\frac{7}{10}$ inches)....	·170
Distance from front margin of first costal to back margin of seventh costal (slightly over $6\frac{1}{2}$ inches)....................	·167
Maximum breadth of carapace ($8\frac{4}{10}$ inches)...................	·214
Length of second neural.	·023
Maximum breadth of second neural.........................	·017
Thickness of fourth costal at centre near inner end............	·005
Thickness of fourth costal at centre near outer end....	·005
Thickness of eighth costal at centre..........................	·005

Trionyx planus,* Owen and Bell, a British Lower Eocene species, described from the posterior half of the carapace, bears a strong general resemblance to *T. foveatus* as regards the sculpture and also in the absence in both species of the seventh and eighth neurals accompanied by a similar curtailment of the sixth neural. The strong development of the seventh costals found in the Red Deer river carapace resulting in a reduction of the eighth pair of costals may be an irregularity of growth of no specific importance.

The second species of *Trionyx* represented by an almost complete carapace is referred to *T. vagans*, Cope, first described by that authority in 1874† from 'a number of fragments of costal bones and perhaps of sternals also,' from the 'Lignite cretaceous of Colorado; near the mouth of the Big Horn river, Montana; Long lake, Nebraska; found at the last two localities by Dr. Hayden.' Later, in 1875, in 'The Vertebrata of the Cretaceous Formations of the West' the same description appears; this time with figures of two fragments of costal bones. Dr. O. P. Hay, of the American Museum of Natural History, New York, has kindly compared part of a costal plate from the Red Deer river with fragments labelled *T. vagans* by Professor Cope in the New York collections. Owing to the insufficiency of the published description and figures of this species, the writer could scarcely judge whether the Canadian specimens were or were not referable to *T. vagans*, but Dr. Hay writes that he thinks they probably are.

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* Monograph of the British Reptilia of the London Clay, part I., p. 58, tab. XIXC, 1849, Palæontographical Society.

†Bulletin of the United States Geological Survey of the Territories, 1874, No. 2, p. 29.

The carapace (Plate IV, fig. 4) is broader than long, the breadth exceeding the length by more than one-sixth and it is only moderately convex. In outline, as seen from above, it is flat behind with the sides curving broadly to the front margin, at the centre of which there is a shallow concavity. The shell protrudes where the ribs pass outward from beneath, causing the lateral margin to be sinuous, the sinuosity being most marked toward the front in the first, second and third pairs of costal plates. Of the eight pairs of costals, the first costals are the broadest at the inner ends, whilst the fifth are the broadest distally. The seventh costals are extremely narrow throughout their length and the eighth pair is well developed. The first costals increase in breadth rather suddenly at their outer ends and are separated by a divided first neural plate. The neurals gradually decrease in breadth to the fifth, their sides being not so nearly parallel to each other as those of the corresponding plates in *T. foveatus.* The sixth and last neural is very much reduced in size and is irregularly oval in outline. Of the protruding rib-ends, all the six of the left side were secured, in a fair state of preservation, except the one belonging to the first costal and it was obtained in part. The rib-heads are well developed. In the figure, the nuchal plate is represented as entire. Of the carapace under consideration, the central part only of the nuchal plate, extending from the margin in front to the suture behind, was found, but fortunately the left end of a nuchal, of another individual of similar size, showing the left front margin and the suture between the plate and the first costal with part of the latter adherent, supplied the deficiency. The sculpture consists of a network of narrow ridges ramifying and inosculating so as to enclose small, sunken areæ of irregular shape and size, the areæ being generally wider than the ridges are broad. The frequent confluence of a varying number of areæ results in a more open pattern, the ridges at times shewing a tendency to run in parallel lines. The sculpture is not so distinctly defined near the sides of the carapace as it is toward and at the centre and anteriorly, but in the hinder part it is more decidedly rugose, the ridges being here higher and the enclosed areæ larger. Near the intercostal sutures, more particularly in the inner halves of the costal bones, the sculpture is partially effaced and consists of low, poorly defined parallel ridges at right angles to the sutures, forming a distinct border, with a maximum breadth of about ·5 centimeters. A smooth border, broadest at the sides of the carapace and narrowest in front, extends along the whole of the peripheral edge.

As regards a divided first neural in species of this genus, it is interesting to note that Lydekker in describing *T. melitensis*, from the Miocene of Malta, in 1891, (Quarterly Journal of the Geological Society, vol. XLVII, p. 37, fig. 1) mentions the occurrence in the Miocene species of a divided first neural and remarks (p. 37) that 'all the fossil species hitherto described, of which the entire carapace is known, agree with the normal type in having but a single long neural between the first pair of costals.'

Measurements :

	M.
Length of carapace along median line (18½ inches)............	·470
Maximum breadth of carapace (23$\frac{2}{10}$ inches)	·590
Breadth of first costal at inner end........	·075
Thickness of same near inner end.........	·009
Thickness of same at outer end...................	·012
Breadth of fifth costal at outer end..............	·119
Thickness of same at outer end.............................	·013
Breadth at mid-length of seventh costal..........	·036
Thickness at centre of eighth costal.....................	·010
Maximum breadth of neural 1.......	·056
Maximum breadth of neural 1a................................	·039
Length of same	·043
Thickness of nuchal plate at left end	·018
Length of vertebral centrum................................	·045

EXPLANATION OF PLATES.

PLATE I.

Figure 1. Upper surface of the carapace of *Trionyx foveatus*, Leidy; from the Cretaceous of Alberta. One-half natural size. The sinuous lines indicate the sutures between the bones; the dotted ones parts restored; NU, nuchal bone; N 1, 2, &c., neural bones; C 1, 2, &c., costal bones.

Figure 1*a*. Outline of the transverse curve of the upper surface of the carapace.

PLATE II.

Figure 2. Upper surface of the carapace shewn in plate I; from a photograph. Considerably over one-half the natural size.

PLATE III.

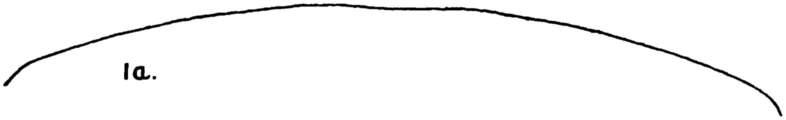
Figure 3. Upper surface of the carapace of *Trionyx vagans*, Cope; from the Cretaceous of Alberta. One-eighth the natural size. Lines and letters as in figure 1 of plate I.

Figure 3*a*. Outline of the transverse curve of the upper surface of the carapace.

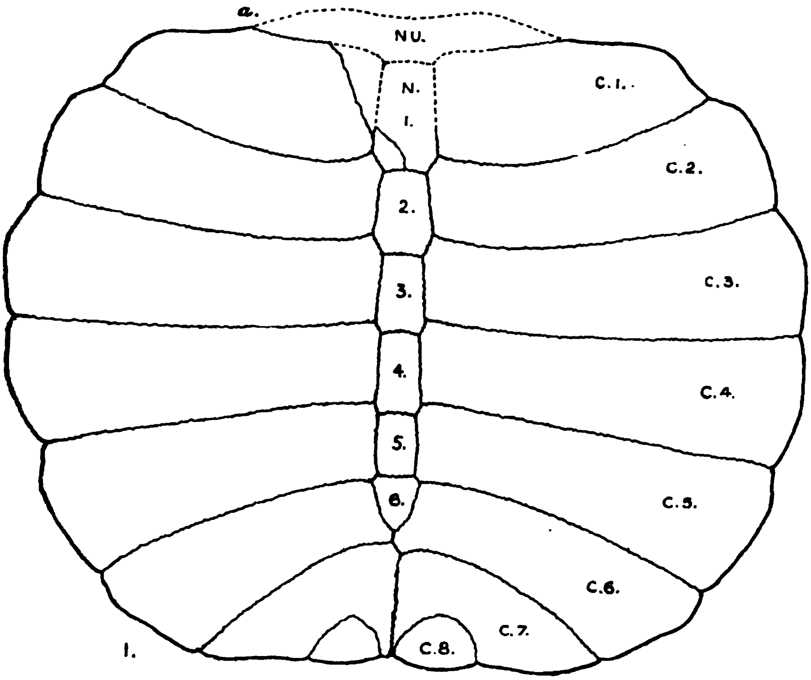
Figure 3*b*. The sculpture of part of the upper surface of the same carapace; from a photograph. Natural size.

PLATE IV.

Figure 4. Upper surface of the carapace shewn in plate III; from a photograph. Slightly less than one-fourth natural size.

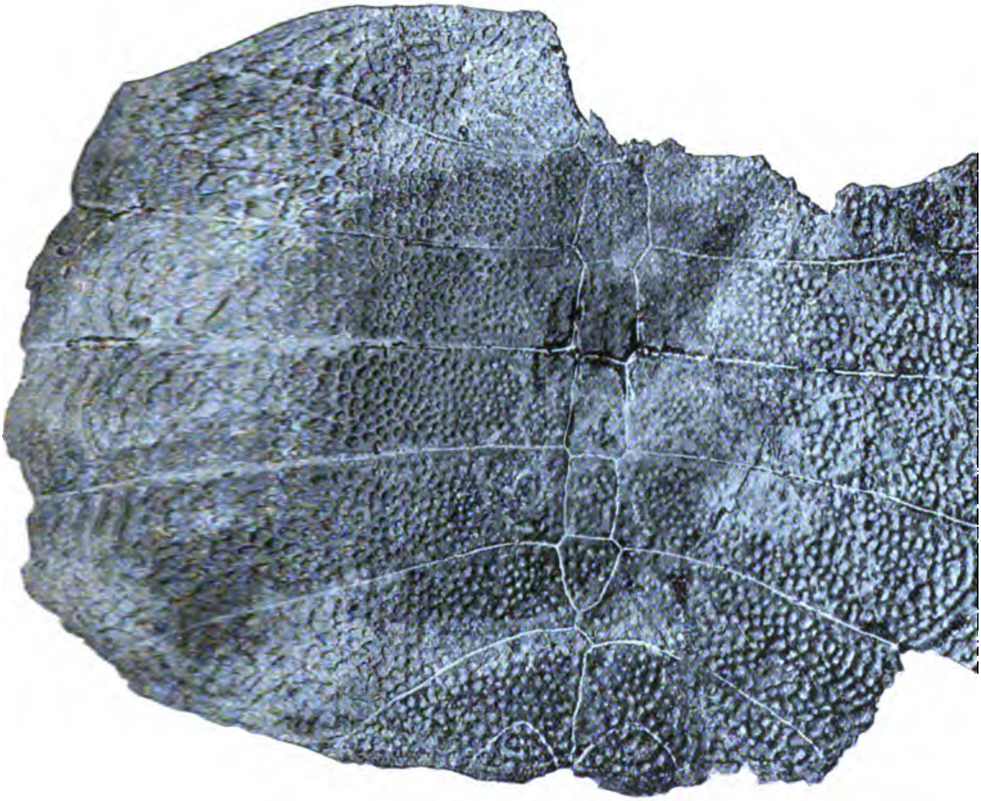


1a.



1.

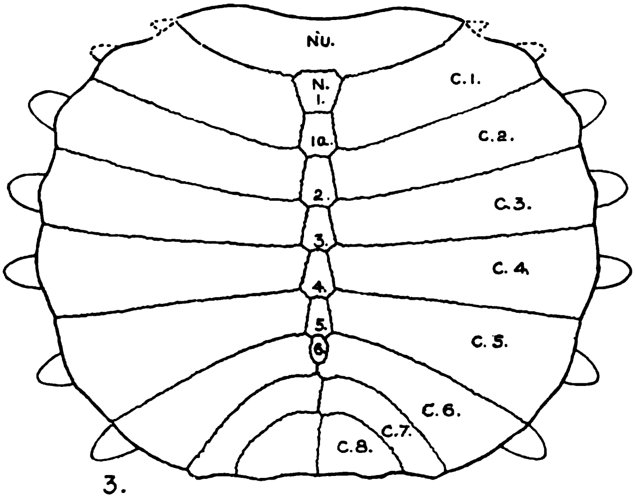
×½



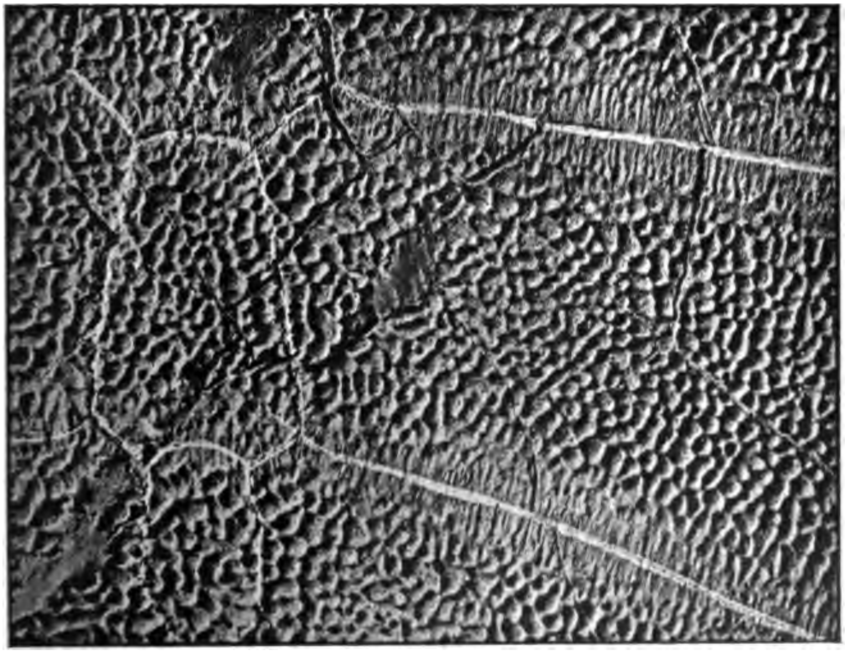
2.

3a.

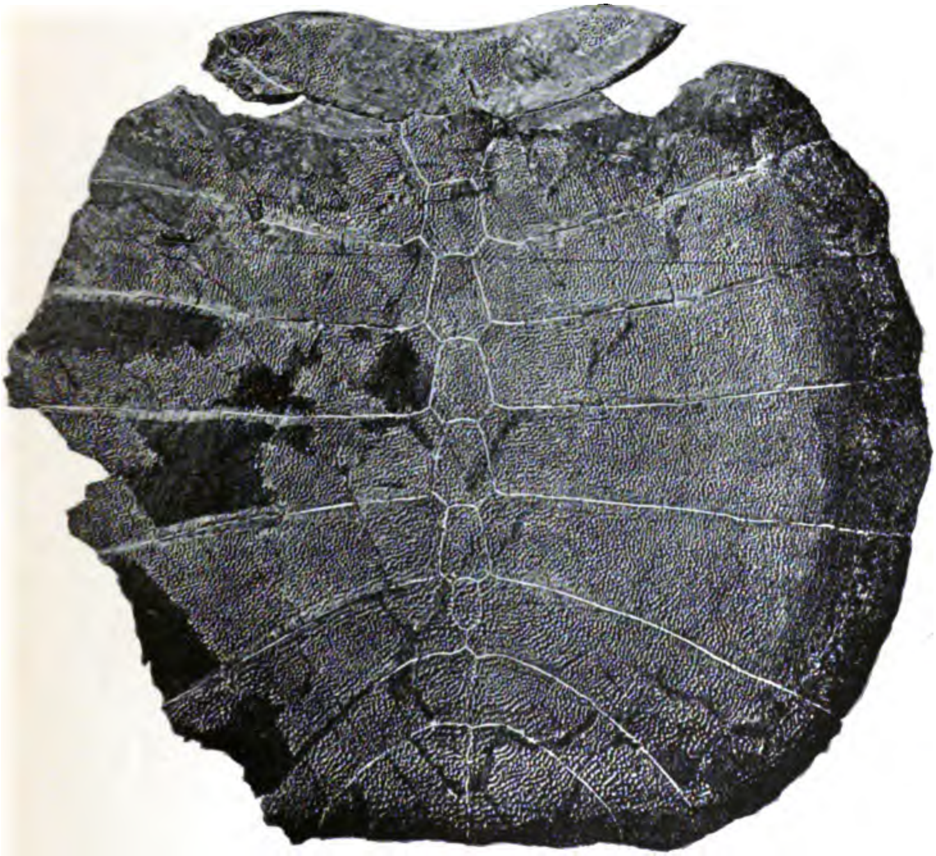
× 1/8



3.



3b.



REGION SOUTH-EAST OF LAC SEUL.

Mr. William McInnes.

The winter of 1900-1 was spent at Ottawa in office work and was chiefly given to the supervision of the compilation of the Manitou sheet and to the preparation of a report to accompany that and the Ignace sheet.

Scope of work.

Pursuant to instructions, the work of the past summer was directed mainly to the completion of the geological and topographical details necessary for the compilation of the geological map-sheet lying to the north of the Ignace sheet. I was accompanied from Ottawa by Mr. A. E. G. Mackenzie, of Campbellton, N.B., who had been appointed as my assistant for the summer. Mr. Mackenzie proved most willing and capable and his services during the summer were of value.

Assistant.

Canadian Northern Railway.

While waiting for canoes at Port Arthur I was enabled, through the courtesy of Mr. Mann, to make a trip to the end of the track on the Canadian Northern Railway, where part of the Atikokan iron belt was examined. At locations 138x and 139x two bands of magnetic iron ore were seen, not apparently of high percentage and shewing considerable sulphur in the form of pyrite. These belts lie about 200 yards to the north of the right-of-way and their outcrop on the hill is perhaps 100 feet above it. This favourable situation led to some exploratory work being done later in the season that resulted, I am informed, in shewing up a band of much cleaner ore. These deposits form part of the Atikokan iron-bearing belt and do not differ genetically from the others that have been described in earlier reports.

Area covered.

The primary object of the season's work was to trace with greater accuracy the Sturgeon lake gold-bearing belt and to work out, as well as possible, the geology of an area of 3,456 square miles lying to the south and east of the eastern half of Lac Seul. A micrometer survey of Sturgeon lake made during the previous summer by James Robertson, P.L.S., for the Ontario Crown Lands Department, was of great assistance and rendered a further topographical survey of that lake unnecessary. In other parts of the area, boat-log and track surveys were carried on concurrently with the geological examination. Starting from Dinorwic station the part of Minnitaki lake not already examined and of which no detailed map was available was first gone over. This lake lies entirely within the Huronian belt that has now been

Gold-bearing belt.

traced continuously from Whitefish bay on Lake of the Woods to the Albany river, having gold-bearing veins at intervals for the whole distance. About the lake, typical Huronian (Keewatin) rocks everywhere occur, the greater proportion consisting of basic eruptives and their derived schists, with a considerable development of more acid eruptives of quartz-porphyry types and of altered sedimentaries. Work was being done on two of the numerous gold locations on the lake, viz., on Twin lakes, near the inflow of English river and at Grassy Narrows.

Conglomerate at Abram lake.

Continuing through Abram chute to Abram lake, the belt is crossed nearly at right angles to its general trend, and a good section of the rocks is afforded. At Abram lake, an interesting conglomerate, noted by Dr. Bell in 1871, is strongly developed, outcropping in a striking way to form a chain of islands that, with projecting points on either shore, nearly cut the lake in two. This conglomerate is made up of pebbles, from quite small to two feet or more in diameter, enclosed in a felspathic green schist matrix, the pebbles being well-rounded and water-worn, like beach pebbles. They include granite and granite-gneiss (in greatest proportion), fine banded gneiss, schist, flinty quartzite, diorite, and white vein-quartz.

Conglomerate belt.

The strike of these outcrops is N. 60° E., and they may be traced on this course to Little Vermilion lake to the west, where both conglomerates and associated quartzites are well exposed, and up the Sturgeon river to the east. Continuing towards Lac Seul, the northern edge of the Huronian belt is reached at the northern side of Pelican lake, and from this point northward, biotite granite-gneisses are continuous, striking N. 60° E. with minor, local variations. At Abram lake a number of locations for gold have been taken up, but little work has yet been done.

English river.

The descent of the English river between Minnitaki Lake and Lac Seul, estimated by barometric readings, is in the vicinity of twenty-five feet, the main drop occurring at the lower end of Pelican lake, where, by a fall and rapid, the river descends about eighteen feet. A small rapid at the entrance to Abram lake, one at the outflow and another below the forks, are the only other breaks in the continuous smooth navigation to Lac Seul.

Falls and rapids.

Fork of English river.

At nineteen miles above the lake, the river divides into two channels, emptying into the lake at points fifteen miles apart and forming an island about 100 square miles in area. The shores of Lac Seul were followed in a westerly direction only as far as the Hudson's Bay Post, biotite gneisses occurring all along with a uniform trend about N. 60°

E. Many of the islands and the north shore of the lake are drift-covered, the drift consisting of clay with overlying stratified sands containing boulders and pebbles of gneiss, of various types of Huronian rocks and of limestone, dolomite and flint holding fossils of Devonian age that probably indicate a glacial origin from the Devonian areas near James bay. The shores of Lac Seul were examined to its head at the falls on the Watap or Root river. The same biotite gneisses occur all along. They are in many places garnetiferous, the crystals of garnet in some of the coarser pegmatitic beds reaching a fair size—a quarter of an inch in diameter. Only at one point, on the south shore above Vermilion river, is there any marked change from the prevailing Laurentian type of rock. Here, though still gneisses, the finer, black bands increase in volume and show many of the features characterizing an approach to the schists of the Huronian. Though no rocks unmistakeably Huronian were seen, there is good reason to infer their presence at no great distance.

Lac Seul drift area.

Huronian.

The drift area already referred to extends easterly for some distance along the north shore, shewing at a number of places, well-marked terraces rising about thirty feet above the lake level. No veins carrying valuable minerals in any quantity were seen about the lake. The principal feeders flowing into this half of the lake are the Watap at the head of the lake, the Vermilion from the south-east, and the Wapessi, a large river entering the lake from the north above the eastern narrows and draining a number of lakes of good size.

Terraces.

Returning towards the railway, Vermilion lake and Little Vermilion lake were examined. The Huronian band of Minnitaki extends westerly beyond these lakes, petering out however before reaching the English river again. This westerly extension of the belt has been prospected for only a short distance west of Vermilion lake, owing largely to the fact that a considerable thickness of drift is reported to overlie the greater part of it.

Vermilion lake.

Vermilion lake is a large body of clear water about 9 miles long by a mile and a-half wide, and varying in depth from ninety to a hundred and twenty feet. Besides the common fish of the district it abounds in maskinongé of good size. Typical Huronian rocks occur all about the lake, including a considerable thickness of quartz porphyry. At the eastern end of the lake a deposit of fine granular iron pyrites of considerable size outcrops at the shore. Its exact extent could not be determined, owing to the covering of drift, but a width of over ten feet was seen at the outcrop. A deposit of red oxide derived from this, colours the beach pebbles for some distance and gives the lake its name of Wunnummini (Vermilion) lake.

Iron pyrites.

Conglomerate at Little Vermilion lake.

On Little Vermilion lake the schist-conglomerate of Abram lake is again seen evidently forming a persistent band between the two and associated with thick beds of quartzite similar to that of Sturgeon lake and the Matawin river. Three portages, aggregating a little over a mile and a-half in length lead, by way of two small lakes, to the south-western arm of Minnitaki lake.

Sturgeon river.

After laying in a further supply of provisions at Sandy lake, Sturgeon river was ascended to the lake. From its outlet into Abram lake, the river is a succession of lake-like expansions, as far as the first fall and portage, a distance of ten miles. For this distance it follows the Huronian belt, the southern edge of the gneiss lying from half to three-quarters of a mile to the north all along and cutting some of the northerly expansions, the immediate contact being in low land without outcrops. About a mile below this first portage, development work has been commenced on a vein, four to five feet wide where exposed at the shore, in a mineralized quartz-schist band, a fissured and crushed form of the banded quartzose felsite. A shaft, sunk on this band close to the vein, was filled with water. The dump showed principally schist with irregular lenses of bluish quartz impregnated with iron and copper-pyrites. This vein is claimed to carry good gold values.

Dog river.

Just above the portage, a large tributary comes in on the right bank carrying perhaps a third of the water of the river. This branch of the river is known to the Indians as Dog river (Annim-o-sibi). For the first nine miles from its mouth, the river lies in the granite-gneisses when it crosses an arm of Huronian felsites, diorites and schists which is probably a continuation of that crossing the Sturgeon river at the portage. Above this band the gneisses again come in. There are in all fourteen portages on the Sturgeon river, aggregating about two miles in length and showing a rise between Abram and Sturgeon lakes of about 160 feet. On Sturgeon lake, the survey made by James Robertson, P.L.S., in 1900, was used, and attention was given only to the geology and to surveying tributary lakes and streams. The outlines of the gold-bearing Huronian were found to be irregular in the extreme and could only be fixed by traversing all the smaller lakes and streams in the neighbourhood.

Portages.

Survey of Sturgeon lake.

Prospecting for gold.

Much prospecting work was done during the summer and many gold claims were located. On only about half a dozen of these had any development been done. On one location, owned by a St. Catharines syndicate, with the precipitancy so characteristic of the earlier years in the district, a five-stamp mill was erected and worked during part of the summer with good results in the amount of gold extracted. Development was not, however, sufficiently forward and it was wisely resolved by the present manager, Mr. Smaile, to close down the mill and give all attention during the winter to sinking a shaft and further proving the property.

Sturgeon lake mining Co.

On the location lying to the east of that on which the mill is situated, a vein has been partly uncovered in the schists. It has been traced at intervals by large bunchy outcrops of quartz for a considerable distance, in a direction about 15° E. of N. One of these bunches has proved phenomenally rich in nuggety gold at the surface. Owing to disputed ownership, only a little preliminary stripping has been done.

Gold locations.

Another property on which extensive surface development has been done is the St. Anthony Reef, lying near the contact between the Laurentian and Huronian, a little south of the Dawson property, above referred to, and between Sturgeon and Couture lakes. There is here an arm of highly altered intrusive granite which, though not as far as seen, connected with the main body of granite-gneiss, is probably genetically the same. Along the contact, a broad zone of shattered rock, upwards of 200 feet wide, is filled with secondary quartz in the form of small veins, lenses and stringers. Where an open cut has been made from the contact westerly into the crushed zone in the granite it is seen to be made up largely of quartz with the included minerals, zinc-blende, galena, chalcopyrite and pyrite occurring segregated in quite distinct coarsely crystalline masses. A pay streak with very high values has been partially traced out, and it is claimed that the whole mass is milling ore. In the schists, the vein contents are more evenly distributed and less coarsely crystalline. The contact between the green schists and the granite mass follows a very irregular course, and the vein, with a general strike nearly north, breaks away into the granite to the north and into the schists to the south, where the contact abruptly changes its direction. Sinking is being prosecuted, and the property is provided with engine house, power drills, &c., with the necessary buildings for the accommodation of the workmen and staff.

St. Anthony Reef.

Contents of vein.

A little further down the shore, Mr. Symmes was doing development work on a vein that seems to be really a crushed band in the granite-gneiss close to the contact. The vein is generally narrow but swells into large pockets of mineralized quartz, seven or eight feet wide. Argentiferous-zinc blende and galena, with pyrite and free gold, occur in the vein, the narrow, more vein-like portions being exceptionally rich.

Locations.

Between the two last noted localities and near the same contact, on location 694 are seen veins running about N. and S. and E. and W.

Location 694.

They occur in a somewhat felspathic green schist and have the lenticular character so common. Sufficient work had not been done to afford information as to their extent. They show visible free gold and native copper in small quantity. At location 207, the property of the Anglo-Canadian Gold Estates, considerable stripping had been done under the supervision of Mr. Girard on a vein running N. 10° E. through green schists, near their contact with an arm of highly altered granite. The vein is lenticular in character and varies in width from seven or eight feet to quite a narrow streak, and is in places rich in visible free gold. It follows partly the line of contact, but is better defined where it has the green schists on both walls. Pyrite, chalcopyrite and a little native copper also occur in this vein. On the opposite side of the Huronian belt, at Belmore bay, a number of properties have been taken up and some work has been done in the way of stripping and showing up the veins.

Location 207.

Belmore bay.

With the object of tracing further the Sturgeon lake gold-bearing belt, a northerly route was followed to the Albany river. Leaving the northerly arm of Sturgeon lake by a small brook entering ten miles north of the outlet and ascending the brook for two miles, a portage of two miles led to a lake about a mile in length. From the head of this lake a portage of thirty-five chains took us to a long narrow lake extending north for over four miles, from which the large lake known to the Indians as Musipomigut and roughly indicated on existing maps under the name Savan lake, was reached by a quarter of a mile portage. A log-survey of the lake proved that there was little or no resemblance between the real lake and its representation on the existing maps. We found it to be a little over twenty-three miles in length in a direction about N. 20° E., having a central portion forming the main lake eleven miles long by five miles wide, with a number of bays of considerable length branching from it. The Huronian belt of Sturgeon lake was found to be continuous almost to the foot of the lake, the two arms, one running northerly to the outlet and the other north-easterly, extending into the granite-gneisses on either side of the central belt.

Route to Musipomigut lake.

Huronian belt.

Description of lake.

The lake is characterized by many shallow bays that are divided from one another along the shore-line by long and irregular rocky points, and at their heads, by areas of swamp. The central part of the the lake shows wide expanses of deep water, while the narrower parts and the bays are for the most part exceedingly shallow, long stretches having only a few inches of water covering a bottom of slimy mud. The forest growth is for the most part of small size and consists principally of black spruce, poplar and white birch, with occasional red and white pine. This is the highest latitude (about 50° 35') in which I have observed the white pine in this district.

The Huronian rocks are of the usual kinds, with a large proportion of massive igneous types, and include a considerable thickness of schists, conglomerates and quartzites, similar to those that occur in the same belt at Sturgeon, Abram and Vermilion lakes. A drift-covered area or basin similar to those occurring in other parts of the district, occupies part of the shores and islands of the central part of the lake. The close resemblance of this drift area to that at Lac Seul makes it probable that they are similarly derived. That at Lac Seul seems to have been laid down at the foot of a glacial barrier which cut off the drainage to the north, and so formed a lake-basin between it and the higher land to the south. Pebbles in this drift contain fossils that seem to be of Devonian age and are probably derived from strata of that age, occurring to the north near Hudson's bay. The derivation of the drift about this lake is the more interesting as colours of gold have been obtained from it. A number of pits near the shore of one of the islands showed the work of the alluvial prospector during the summer. I could not learn authoritatively that more than a few colours had been obtained.

Drift basin.

Traces of alluvial gold.

Many smaller lakes were visited and surveyed during the summer, including a chain lying between the western end of Sturgeon lake and Sturgeon river. Of these the largest is known to the Indians as Kashapwaweigamok (Straight route lake), as it affords a short and easy route from Sturgeon river to English river and the railway. The lake lies within the granite-gneiss, only its extreme south-western bay reaching down into the Huronian, where it approaches the northern end of Jarvis lake on English river. This Sturgeon lake area was visited by a great number of prospectors during the summer, some of whom extended their field north to some distance down the Albany river, following the same belt of rocks.

Straight route lake.

Prospecting parties.

A well marked iron-bearing belt was noted to the north of Sturgeon lake, extending from the lake to the south of Musipomigut for some distance up that lake. No deposit of commercially valuable iron ore was seen, the outcrops being confined to very narrow bands of magnetite in the schist or very fine gneiss.

Iron belt.

Active work is being continued during the winter at the Shore property on King bay, at the Sturgeon Lake Mining Company's and at St. Anthony's Reef, as well as, probably, on a few others.

Mining in progress.

The Country West of Nipigon Lake and River.

Dr. Alfred W. G. Wilson.

Nomenclature of rivers and lakes.

In naming lakes or rivers in this report, as far as possible, an English translation of the name by which the water-body is known to the Indians has been used. At present there is much confusion in regard to the names of many of them, because different surveying or prospecting parties have given different names to the same body of water, without any regard to those used by the natives of the district. For example, on the field-map received from the Geological Survey office at Ottawa, there is a small sheet of water just east of Black Sturgeon lake, named Pike lake. On the map published by the Ontario Goverment this summer, the same lake is called McKee lake. To the Indians, the lake is known as Kawawata or Northern Light lake, and the latter name is used in the present report. Again, the lake just east of this is Fraser lake of the Ontario map, Kahwahzehbemegog of the field map and the natives, and the Indian name is here translated Pleasure lake; Lake Elizabeth of the field map is called Susie lake on the Ontario map, and as the Indians have no name for this lake, priority holds and the lake is referred to as Lake Elizabeth in this report.

Work by Dr. Wilson.

On receiving a letter from the acting Director of the Geological Survey, dated June 17, 1901, intimating that I had been appointed to make a geological survey in the district south and west of Lake Nipigon, I reported to the Department personally in Ottawa on June 21st. Leaving Ottawa on June 26, I joined Dr. W. A. Parks in Toronto. Together we proceeded to Port Arthur, reaching that place on July 1, our steamer having been delayed by a storm on Lake Superior. After procuring the bulk of our supplies for three months, and engaging two canoemen in Port Arthur, we went to Nipigon station on the Canadian Pacific railway, where our canoes and camping outfits already awaited us. At Nipigon, Mr. Thomas M. Fyshe of Montreal, who was to act as my assistant during the summer, reported to me.

Assistant.

Parties separate at Lake Emma.

Moving into camp at the foot of Lake Helen on July 3, we commenced our ascent of the river the next day. On July 5 and 6 we were somewhat delayed by rains, but reached Lake Emma on July 8 where I parted from Dr. Parks, he proceeding up the river while I turned to the west through Lake Hannah. After making a track-survey of South bay from Lake Hannah and examining the rocks in that vicinity, we crossed the Flat Rock portage to Lake Nipigon. Three days were spent surveying some small streams which enter South bay from the south, and in studying the geology around the bay. On July 12 we started for Chief's bay on the southwest side of Lake Nipigon, noting the geology of the peninsulas lying on either side of McIntyre, Grand, and Black Sturgeon bays. While in the vicinity of the Indian Mission on McIntyre bay, our Indian canoeman deserted, causing however a delay of only a few hours, as we were fortunate enough to secure the services of a much more efficient canoeman at the Mission.

Poshkokagan river.

On July 16 we reached the mouth of the Poshkokagan river and commenced a track-survey of that stream, beginning at the head of the first rapids. On July 18, having reached a point about two miles above the foot of the long rapids, and about eight miles from Chiefs bay, I left Mr. Fyshe in camp and proceeded with the Indian to the point were the Canadian Pacific exploration line crosses the river near Poshkokagan lake. Returning a short distance, we proceeded up Lime creek, a tributary of the Poshkokagan from the south, for a distance of about six miles and then across country due east to the headwaters of Birch creek, another tributary of the Poshkokagan. Descending Birch creek we reached our camp on July 20. Returning to Chief's bay, a survey was made of several small brooks which enter that bay from the north. On July 25 we crossed to the Kabitotiquia and descended that river to Gull bay, studying the geology *en route*. On Gull bay, a survey was made of a small lake and brook lying to the south of the east arm of the bay. From here we proceeded to Nipigon House to procure further supplies and to secure another canoeman, as the man then with us declared himself unable to work longer on account of injuries received some time before while portaging a heavy canoe.

Short surveys made.

Leaving Nipigon House on July 29 we proceeded to West bay to examine the geology in that vicinity, and thence down the west shore of the lake towards Black Sturgeon bay, making a survey of Flat Rock Point bay and studying the geology at several points *en route*. After spending a couple of days in the country immediately to the east of Black Sturgeon bay, we crossed the portage to Black Sturgeon lake. On reaching this lake the canoeman from Nipigon House became sick and practically useless. He was permitted to leave with a prospector and two Indians, a message being forwarded to the manager of the Hudson's Bay Company's store at Nipigon station asking that another man be sent. The company's agent kindly secured a man to come from that post to our camp on Black Sturgeon lake, and he

Delayed at Black Sturgeon lake.

joined us ten days later. The interval was spent by Mr. Fyshe and myself in studying the geology and topography of the country around Black Sturgeon lake, more particularly in attempting to work out the relations of the Laurentian and newer rocks immediately to the east of the lake, a number of traverses being made across the Laurentian belt.

Work accomplished.

On August 15 we were joined by the canoeman sent by the Hudson's Bay Company from Nipigon, and immediately proceeded to the portage leading to the head-waters of a small river which enters Black Sturgeon lake about the middle of the west side. On August 24 we returned to the lake, having reached a point beyond the western boundary of the map-sheet and having mapped seventeen small lakes (and connecting streams) on this system, the largest of which, Circle lake, is about three square miles in area.

Ascend Nonwatin river.

Descending the Black Sturgeon river, we reached Nonwatin lake on August 26, and on the 27th started to ascend the Nonwatin river, a swift and shallow stream with many rapids, making a track-survey of it as we went along. Being delayed somewhat by rains, we did not reach Small Trout lake, near the southern boundary of the sheet, until August 31. From this lake, trips were made to the south-west, ascending the Upper Nonwatin to beyond the boundary of the sheet and to the north-west as far as Small Trout lake on the Spruce river. From the south end of Small Trout lake we made a section directly east to the Black Sturgeon river, surveying Sucker lake near the head of Sucker creek *en route*. Returning to Nonwatin lake on September 9, a day and a half was spent in examining the country to the east of the lake. On September 12 we started towards the Nipigon river over a portage route leading from the foot of Nonwatinose lake to Northern Light lake and thence through Pleasure lake, Lake Elizabeth and a few smaller lakes to Lake Maria on the Nipigon river. Surveys were made of a few small lakes, and the northern boundary of the Laurentian area, which lies between Nipigon and Black Sturgeon rivers, was mapped.

Assistant returns home.

On reaching Nipigon station on September 21, I paid off the canoemen and Mr. Fyshe, the latter returning home on account of an injury to his knee. After spending two days in refitting and in engaging four canoemen, on September 25 I left Nipigon by rail for Sprucewood siding, near the Black Sturgeon river. Commencing at the Canadian Pacific railway crossing, we made a micrometer survey of the Black Sturgeon river as far as Nonwatin lake, reaching the latter point on October 3, having been materially delayed by snow and sleet storms. From Nonwatin lake we proceeded to Black Sturgeon lake and commenced a micrometer survey of the Spruce river (upper Black Sturgeon), carrying the line to about three miles above Muskrat lake, on the north branch of this stream. Above this point the river is very narrow, and a long portage leads to a small lake at the headwaters of this branch, but on account of the lateness of the season I did not think it advisable to ascend further. Returning to a point about three miles from Black Sturgeon lake, we portaged across to Small Sturgeon lake, on the south branch of the Spruce, and descended this river, which is chiefly a succession of rapids, to Black Sturgeon lake.

Mecrometer survey of Spruce river.

After spending a day and a-half in visiting Tchiatangs bluff on the east side of Black Sturgeon bay, Lake Nipigon, to study the relations of the rocks in that vicinity, and a portion of the day in visiting the belt of iron-bearing strata near the south-east corner of the lake, we ascended the Spruce river to Small Sturgeon lake and commenced a micrometer survey of the upper part of the river, carrying the line up to and across the height-of-land and coming out on the stream which enters East bay of Dog lake from the northeast. The lateness of the season and a shortness of supplies rendered it inadvisable to attempt to reach Eaglehead lake and several other small lakes on the Eaglehead river, a small stream which enters Spruce river at a point about eight miles from Small Sturgeon lake. I determined to descend the Kaministiquia from Dog lake and reached Kaministiquia station on the Canadian Pacific railway on October 30. Returning to Port Arthur next evening, a day was spent there in settling accounts, and two days at Nipigon station in paying off the men and in packing up the outfit for the season.

Line run from Spruce river to Dog lake.

Geology of the Area.

The rocks of the country traversed during the season belong to the Laurentian, Huronian and Cambrian, the last mentioned being represented by the Animikie formation.

Geology.

Laurentian.—Beginning south of the southern boundary of the area, extending northward as far as Lake Maria, and reappearing from beneath the traps of the Animikie formation at several points (noted by Dr. Parks) above this in the valley of the Nipigon river, is a belt of Laurentian rocks, chiefly gneiss. The northern boundary of this belt curves south in the vicinity of Lake Maria, along whose western shore the gneiss occurs in a narrow belt. From the foot of Lake Maria it runs west and then northward to the foot of Lake Elizabeth. From

Area of Laurentian rocks.

here the boundary runs a little south of west, lying but a few chains north of the outlet stream from Pleasure lake. From near Nonwatinose lake a belt of Laurentian, varying from one to two miles in width, runs northward, appearing on the east shore of Black Sturgeon lake near the long point, outcropping east of the portage from Black Sturgeon bay, and reappearing from beneath the traps of the Animikie along the base of Tchiatangs bluff, which forms the eastern side of this bay. Similar rocks outcrop in a very narrow belt, about one mile in length, along the southeast side of Grand bay, and are also seen at Gneiss island in the passage between Grand and Black Sturgeon bays. The western boundary of the main area of Laurentian is approximately marked by the Black Sturgeon river from Nonwatin lake to beyond the southern boundary of the sheet. The rocks consist of alternate belts of black micaceous schists and of pink to gray hornblende-biotite gneisses, moderately fine grained in texture. In the vicinity of Nonwatin lake and east of Black Sturgeon lake, there is an area of pink to gray hornblende granite which frequently becomes a granitoid gneiss. The relationship of the granite and older gneisses is very complicated, so much so that at times it is difficult or impossible to determine any line of demarcation between the two.

Western boundary of main area.

Area of biotite-granite-gneiss.

To the southwest of the sheet, around the headwaters of the Spruce river, the biotite-granite gneisses, so well developed in the area of the Shebandowan sheet, were found uncovered around the shores of a small lake to the north of Ell lake, the main area occurring in the vicinity of Ell lake and from thence southward. The strike of the foliation planes of the gneisses and schists in the region preserves a uniform direction of about fifty-five degrees east of north, with variations reaching a maximum of about thirty degrees on either side of the normal.

Huronian.

Huronian.—Within the boundaries of this portion of the sheet there is but one small area which may be considered to belong to the Huronian. Commencing near the south-east corner of Black Sturgeon lake and extending south-east to the vicinity of Nonwatinose lake, is a narrow belt of highly ferruginous quartzite of an average width, so far as could be determined, of about four hundred yards. On the north-east, this quartzite band, whose beds strike N. 20° E. and are nearly vertical, is cut off by the granitoid gneiss belt referred to above, while on the south-west it is overlaid by later deposits. About half a mile east of Black Sturgeon lake, the quartzites are interbanded with a red hematite, sometimes quite soft, in bands rarely over a foot in width. The outcrop at this point is small, but from the topographic features of the vicinity one would expect that a much larger body of soft ore would be found in the valley near the outcrops, which are on the side of a steep incline.

Red hematite bands.

Further east, other small exposures of the ore occur, but the drift covering makes it impossible to determine their extent and value without considerable stripping. I understand that locations have already been taken up along this belt, although I was unable to find any claim-stakes in the vicinity of Black Sturgeon lake. Claims have been staked north of Nonwatin and east of Nonwatinose lake. No development work of any kind has as yet been undertaken, and the value of the belt has still to be proved. The ores which I have seen vary from a soft unctuous clay-like mass of bright red hematite to a hard ore, in which are frequently found small patches of sparkling blue-black hematite. I was informed that specular hematite in larger masses has also been found in this vicinity.

Claims said to be taken up.

Area of Animikie.

Animikie.—The bed-rocks of the greater portion of the area belong to the Animikie formation. These rocks are of several types, that of greatest extent in the region I examined, being a deep red dolomite, frequently brecciated. It sometimes occurs in beds about 1 foot in thickness and then it is usually fine-grained and compact; at other times it is quite shaly and may then be coarser grained. Frequently it is yellow-spotted, owing to a partial reduction of the iron oxide, and occasionally small crystals of gypsum (selenite) are found. This dolomite is well exposed along the Black Sturgeon river below the lake of the same name, and along the Nonwatin river to beyond the borders of the map-sheet. Associated with these dolomites is a highly ferruginous dolomitic sandstone, best exposed along the valley of the Spruce river. This sandstone frequently carries large inclusions of quartz in angular masses. Both of these rocks occur in beds, which, near the Black Sturgeon river, are slightly inclined toward the south-west, and which, near the boundary of the sheet on the upper Spruce river, have a dip of five degrees to the east. Small outlying areas of the dolomites occur on the east shore of Black Sturgeon lake about two miles from the outlet, and also on the west and south shores of Northern Light lake. On the Upper Spruce river near the southern boundary of the sheet the red dolomites are conformably overlain by thirty-feet of a fine-grained greenish grey hard-shale, lacking slaty cleavage, and showing many fossil mud-cracks but no organic remains. This hard shale is capped in this locality, by fifteen feet of trap, and all three rocks dip to the east at an angle of five degrees.

Associated ferruginous sandstone.

Outlying areas of dolomite.

A rock of very wide occurrence within the district is a fine- to coarse-grained extrusive, which, pending a microscopic examination, may be called trap. The trap rock, as it occurs in this region, is probably chiefly gabbro, though there are areas in which it shows a distinct diabasic structure. The trap frequently contains enough magnetite to

Large areas of probable trap rock.

seriously interfere with compass observations. The traps are found to cover the greater portion of the area between the Nipigon river and the Poshkokagan, and from Gull bay to the southern boundary of the sheet. To the south of McIntyre bay, the trap forms an almost continuous sheet. Westward in the vicinity of the Poshkokagan, Spruce, and Nonwatin rivers, it occurs in ridges and more rarely in isolated hills. Along the west side of the Black Sturgeon river, and near the upper Nonwatin and upper Spruce rivers, the trap, in a sheet varying in thickness from fifteen to three hundred feet, overlies the sedimentary beds, apparently conformably. In the vicinity of Grand bay and Black Sturgeon lake it is found to rest upon the Laurentian.

Modes of occurrence.

On the east side of the passage between Black Sturgeon and Chief bays and in the vicinity of Tchiatangs point on Chiefs bay are small exposures of a compact greenish dolomite in beds, varying in thickness from one to six inches and apparently resting conformably upon the trap, which is here very fine-grained at the contact. On the east side of Tchiatangs point, about two miles from the extremity, similar dolomites are found, apparently overlain conformably by a trap sheet which is here over one hundred feet in thickness. A lithologically similar dolomite is found in a position apparently overlying the trap and covering about six square miles on the southwest side of McIntyre bay.

Dolomite beneath trap.

Two sheets of trap.

In the front of the bluff along the south side of Grand bay is found a granophyric dyke, intrusive in the lower traps, but overlain by the traps which form the crest of the bluff. These two cases of trap sheets of considerable thickness, overlying other rocks closely associated with trap, suggest that there are at least two trap sheets of somewhat different ages in the region.

Along the southern part of Black Sturgeon bay and extending south as far as Black Sturgeon lake is a very narrow belt of sedimentary rock, chiefly sandstone. The lower beds at the south end of the belt are conglomeritic and contain a few fragments of the schists upon which they rest. At the northern end of the belt these sandstones are both overlain and underlain by trap. At the north end, where they are in contact with the trap, these beds dip at an angle of fifty-five degrees to the westward and strike N. 10° E. At the point of contact with the schists the dip is about thirty-five degrees to the south-west. In one place the sandstones in contact with the trap were found to stand at an angle of eighty degrees to the horizontal. On the eastern side of the Laurentian belt, which traverses this portion of the area, a somewhat similar sandstone occurs in positions varying from nearly horizontal to a dip of about sixteen degrees to the south-west. The sand-

Sandstones.

stones of this belt, which is nearly a mile in width, are almost free from iron oxide, are generally white, and are probably newer than the first extrusions Their aggregate area approximates eight square miles.

Dolomitic limestone.

In the valley of the Poshkokagan river, beginning at a point about eight miles from Chiefs bay and extending to within about four miles of Poshkokagan lake, are a number of exposures of almost pure white, occasionally reddish streaked and mottled, dolomitic limestone, readily sectile on the fresh fractured surface, but becoming hard on exposure to the air. The width of this belt is indeterminate on account of the covering of drift and forest, but from the topographic features, it is certainly five miles across and frequently somewhat wider. In the upper part of its course the Poshkokagan passes through a gorge about one hundred and forty feet in depth, cut chiefly in this dolomite.

Topography.

Dissected table-land.

From a physiographic standpoint, the country explored may be regarded as a partly dissected table-land. The best preserved portion of this table-land is found in the region south and west of McIntyre bay, where the flat-topped upland has a breadth of over three miles and consists largely of bare rock with a few small scattered areas of glacial sands, on which there is a growth of stunted jack-pine, black spruce or small poplar. In the west and south-west portion of the sheet, the dissection has proceeded much further, and the trap occurs in ridges and isolated masses between broadly open valleys. The trap caps the older sedimentary rocks, upon which it was extruded, and into which it has probably been locally intruded in the form of laccoliths. The more ancient depressions, now more or less blocked by glacial débris, have become the valleys of the present streams and lakes. The Black Sturgeon river, from the foot of the lake of the same name to within about three miles of the Canadian Pacific Railway crossing, flows along the front of a trap-capped cuesta formed by the dolomites and sandstones of the Animikie formation. On the east rise the older Huronian and Laurentian hills, occasionally capped by traps in the vicinity of Black Sturgeon and Nonwatinose lakes. The Nonwatin and Spruce rivers and their tributaries drain the cuesta outwards after the manner of insequent streams. These streams wander to and fro in broadly open valleys, occasionally cutting into bed-rock, but more frequently cascading over glacial boulders or meandering through glacial and alluvial sands. At the edge of the upland, the Spruce river descends nearly 400 feet in a long series of rapids over trap rock *in situ*, to the level of Black Sturgeon lake. The Nonwatin river, on

Character of valleys.

the other hand, descends from the upland over red dolomites. Both rivers, it will be noted, flow northward for the greater part of their courses, turning almost abruptly eastward when about four miles from the cuesta front.

Glacial deposits.

The valleys of the three principal rivers, the Black Sturgeon (and its tributaries the Nonwatin and Spruce), the Poshkokagan and Kabitotiquia, are more or less filled with deposits of glacial origin, either sands and gravels occurring occasionally as eskers or kame-like mounds, but more frequently as sand plains or extensive boulder plains. These latter, particularly in the valley of the Poshkokagan, cover an area more than 100 square miles in extent, forming a typical felsenmeer. Sometimes the boulders are found without a covering of any kind, but in the present case this occurs only in small areas. More frequently they are covered with moss and a dense growth of underbrush and spruce.

Economic Resources.

Farm lands.

There are a few small tracts, particularly in the valleys of the Nonwatin and Kabitotiquia, which are sufficiently free from stones and boulders to be considered fit for agricultural purposes. The areas are, however, small, scattered and difficult of access, and the region, as a whole, must be regarded as totally unfit for settlement.

Iron ore.

From an economic standpoint the country will prove to be valuable only for its timber and for the iron ores in the district near the Black Sturgeon lake and river. The uplands, for the most part, are bare or covered with jack-pine and spruce, or small birch and poplar, generally not large enough to be of any value. The valleys along the river are densely wooded, chiefly with spruce. In a number of areas, particularly on the higher ground and on glacial sand and gravel plains, we find poplar and birch and a few areas of jack-pine. In a narrow belt, rarely over a mile in width, along the valleys of the Poshkokagan and Spruce rivers, there are many very large white spruce trees. One of these, which I measured on the Poshkokagan, was eight feet in circumference three feet above the ground. There are small areas of red pine along the east shore of Black Sturgeon lake, and a few scattered white pines in the vicinity of the same sheet of water and the streams entering it from the west. Both the red and white pine trees are too few in number to be worth cutting except in connection with the other timber.

Timber.

Burnt areas.

In the valley of the Poshkokagan, a belt of timber about a mile in width and about ten miles in length was burned over last year, all the trees being killed. During the present summer there was a large fire in the region west of the Spruce river. The extent of the burned area could not be ascertained. In all about one-half of the region is covered with timber, which will be of value for pulp-wood, or for ties and piles.

Game.

At present the district is the hunting ground of the Indians from the settlement on McIntyre bay. Large game (moose, cariboo and black bear) seem to be abundant. During the summer, members of our party saw, besides the above animals, otter, fisher, mink, beaver, muskrats and foxes. Marten and lynx are also taken by the Indians.

THE COUNTRY EAST OF NIPIGON LAKE AND RIVER.

Dr. W. A. Parks.

Instructions.

My instructions as received from Dr. Bell were to complete as far as possible, the geology and topography of that part of the Nipigon sheet lying east of the lake and river. Owing to the limited time and the rather inaccessible nature of the country it was thought advisable to make track-surveys only, and to tie these to the various exploratory lines which had been run in connection with the location of the Canadian Pacific railway and to the shores of Lake Nipigon. The Nipigon sheet embraces an area of the usual size adopted by the Survey (forty-eight by seventy-two miles). This includes the southern part of Lake Nipigon as well as the Nipigon river to within a few miles of its mouth. Nipigon lake and river divide the sheet into two almost equal parts; the eastern half was assigned to me, while Dr. Alfred Wilson received similar instructions regarding the western division.

Region covered.

First survey of lake Nipigon.

The first work in this region was executed by Dr. Robert Bell with the assistance of Mr. Peter McKellar during the summer of 1869. Dr. Bell triangulated the western side of Lake Nipigon from South bay to the northern extremity, filling in the details with measurements taken by the micrometer telescope, while Mr. McKellar carried out a compass and micrometer survey of the eastern side. Both gentlemen made geological examinations of the shores of the lake and of the lower portions of some of the rivers flowing into it. The resulting map, on a scale of four miles to the inch, was published in the report of the Survey for 1869. At a later date Messrs. D. B. Dowling and Wm. McInnes made a survey of parts of the shores and of those islands which had been omitted in the above survey, and also a compass and micrometer traverse of some of the tributary streams. It will be seen that this left a large amount of work to be done in the interior before a sufficient knowledge of the geology and geography inland had been acquired to justify the issuing of the map-sheet.

Assistant.

During the summer I had the assistance of Mr. Gordon O'Leary, of Lindsay, who proved in every way satisfactory. In company with Dr. Wilson I left Toronto on June 27 and arrived at Port Arthur on June 30. Here we spent a day in obtaining men and supplies and on July 2 proceeded to Nipigon, where we completed our equipment and were enabled to start up the river the following day. Mr. O'Leary had not arrived by this time, so I thought it better to leave word for him to follow, as I desired to lose no time before getting the supplies over the long portages. I parted from Dr. Wilson at the portage below Lake Emma on July 8 and arrived at Rabbit falls the same night. The next day I was joined by Mr. O'Leary and we proceeded at once to Poplar Lodge at the mouth of the Sturgeon river, which point we made our headquarters for some time. Here I purchased a small bark canoe, as the large cedar one with which I ascended the river was much too heavy and clumsy for inland work.

Getting to our field.

Poplar point.

A small stream enters Lake Nipigon a short distance north of Poplar point. In order to ascertain the eastern limit of the Mungo Park trap area and to map the stream referred to, it was ascended to a point beyond which it was found to be entirely unnavigable, Returning from this trip, I had the misfortune to suffer a slight accident which forced me to remain at Poplar Lodge for two days. During this time I sent Mr. O'Leary to make a survey of the large lake lying north of Mungo Park point. This he accomplished and found that the waters of this lake discharge into Lake Nipigon direct, and not into the Sturgeon river, as indicated on former maps.

Sturgeon river.

On July 19, I started up the Sturgeon river but considered it unnecessary to make a survey of its lower part, as this had already been done by Mr. McInnes. On entering Cameron lake, however, I began a track-survey which was carried through to the upper waters of the Sturgeon river. A similar traverse of the Windigokan lakes was also made at this time. On July 25, I left the Sturgeon river and portaged into a chain of lakes which finally brought me to the Blackwater river. On ascending this stream it was found to flow out of a lake about three miles long. A track-survey was made of the lake and of the river to its mouth in Lake Nipigon. The stream is not travelled by Indians and no portages were cut out, hence it took us a considerable time to make the traverse and we did not arrive back at Poplar Lodge until August 1.

Blackwater river.

Various Huronian rocks.

The region, from the Sturgeon to the Blackwater river and for a few miles on each side of these streams, is occupied by various Huronian rocks, including sericite and other schists, altered porphyrite and quartz-porphyry, slate and, more abundantly, diorite, both massive and in different stages of metamorphism. Agglomerates also are found at a few places. The dividing line between the agglomerates and the rocks below them might be drawn from the mouth of the Sturgeon river to a point north of the Windigokan lakes. Particular attention is due to this region as it contains, in places, ranges of schists passing into jasper and hematite. The strike is somewhat north of east in all cases and the dip variable but always near the vertical. Within the limits of the sheet there are, roughly speaking, three ranges with indications of iron*; one just north of the Sturgeon river and two south of it. Many claims have been staked on these belts, chiefly by the Flaherty and Clergue syndicates, both of which are actively and systematically prospecting the region. Mr. Flaherty has had a diamond drill working during the past summer on the first range south of the Sturgeon (the Sand river range). The jasper rock is here 1,000 feet wide and is filled with narrow bands of pure hematite. Its strike is 22° north of east and its dip northward 76°. The drill was driven down 542 feet at an angle of 60° from the vertical to the south, thus crosscutting the deposit. The core revealed continuous jasper with narrow bands of hematite and at the bottom a passage into quartzite. This belt has been traced, with some interruptions, to Little Long lake, a distance of 70 miles to the eastward, at which Dr. Bell mentioned the occurrence of iron ore in his report for 1870. North of the Sturgeon, the strike is about the same, but the average width is difficult to ascertain as the deposit is covered by the silt at the river banks. Slaty hematite, giving 40 per cent iron has been found at different places on this range. I was able to work out the geological conditions of occurrence fairly well and will be in a position to write on this point when the various samples have been examined. Jasper was observed at one place on the Blackwater river and magnetite was found south of Blackwater lake.

Three iron ranges.

Jasper rocks.

Iron at Little Long lake.

On August 2, I re-ascended the Sturgeon river to the Long portage and made an overland trip north, a distance of four miles, in order to locate the northern limit of the large trap area. The following day I started with a month's provisions to examine the chain of lakes lying south of the region above described. Long and rough portages are encountered in ascending the 800 or 900 feet of difference in level between these lakes and Lake Nipigon. Massive hills of trap mark the limits of the Animikie formation and much assisted me in mapping these rocks. Their extent was at one time much greater than at present, as evidences of denudation are very manifest and outliers are numerous, sometimes at considerable distances from the main mass.

Large trap area.

Hills of trap.

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* The iron ore of this region was discovered by Mr. Peter McKellar, assistant to Dr. Bell, in 1869. See Report Geol. Survey, for that year.

New lakes mapped.

It was found necessary to survey all the lakes of this chain, as existing surveys are extremely faulty and in places absolutely incorrect. Many trips inland were made and a large number of new lakes mapped. Particular attention was paid to locating the head-waters of the several rivers flowing into Lake Superior. The height-of-land between the Nipigon and Superior waters lies a short distance south of the above mentioned chain of lakes. The streams flowing south have therefore, more than 1,000 feet descent in a distance of about 25 miles. This renders them very rapid and as the volume is small they are all quite unnavigable. The first ten miles of these streams lie on the uplands, hence lakes are more numerous and the canoe navigation facilitated thereby.

Rapid descent.

Pijitiwabikong.

On September 2 we returned to Poplar Lodge and removed our supplies to a point on Pijitiwabikong bay. The following week was spent in making overland trips in various directions from this place, the most interesting results, besides minor geographical features, being the locating of limestone under the trappean overflow at several places.

Overland to lake Superior.

On September 9, I instructed Mr. O'Leary to engage an Indian and take the large canoe to Nipigon station, while, with one man, I returned in the small canoe to the most south-easterly point reached in the previous trip. From this place we forced our way southwards, discovering a number of small lakes and one of considerable size known to the Indians as Abamichegomog. We were finally forced to abandon the canoe and to make our way overland to the railway. This country is extremely hilly and rough and consists of Laurentian gneiss, but a fringe of Huronian schist is met with before reaching Lake Superior. This trip resulted in the mapping of the Gravel and Cypress rivers and in proving the existence of a large area of excellent spruce timber. On returning from this expedition I paid off the Indian who had been with us all summer.

Long narrow valley.

With Mr. O'Leary, I went to the north end of Lake Sally, from which point a trip was made northward to connect with the one previously made from the south end of Pijitiwabikong bay. This revealed the fact that a narrow valley has been cut through the trap from Lake Nipigon to Lake Helen, as gneiss is found all the way from Pijitiwabikong bay to the latter. In order to survey the Jackfish river, we went overland, due east, until a stream was encountered which we followed to the railway. This proved to be only a tributary of the Jackfish. Another expedition was therefore made along the line between concessions II and III of the township of Ledger and it was continued a mile beyond the borders of the township, where the river was again found and it is thus located at four points, namely on two trial lines of the

Canadian Pacific Railway, at the point just mentioned, and at the junction of the affluent above referred to. These various trips revealed a large area of sandstone, limestone and shale resting on the gneiss and covered by the massive trap. The Jackfish river occupies a wide valley, eroded through the trap and floored at both its northern and southern ends with gneiss, with a wide belt of sandstone and limestone in the middle. It appears to me possible that at some past time the waters of Lake Nipigon escaped from the great chasm at Pijitiwabikong bay and found their way to Lake Superior through the well-marked valley of the Jackfish river.

Sandstone etc. under trap.

The lower part of the Jackpine river I was unable to explore, as my duties in Toronto demanded my return by the first of October. However, two streams were surveyed from the north end nearly as far as the southern boundary of the sheet. It is very likely that these two streams unite to form the Jackpine, as they lie in the proper place and would agree with the location of the river on the plans of the Canadian Pacific Railway.

Jackpine river.

I wound up the business of the expedition at Nipigon station and Port Arthur and, accompanied by Mr. O'Leary, arrived at Toronto on September 30.

THE WEST SIDE OF JAMES BAY.

Mr. D. B. Dowling.

In the Severn district of the Hudson's Bay Company, which has now become the southern part of the District of Keewatin, there is a large region lying to the south-west of Cape Henrietta Maria that had never been geologically explored, and in which we were consequently unable to lay down the boundaries of the formations, even approximately. As this region occupies a very conspicuous position on our geological map of Canada, in course of preparation, it had become necessary to ascertain as much as possible during the season in regard to the distribution of the rocks in these parts. In addition to this, the west side of James Bay had not been surveyed, and as it was desirable to represent this shore on our maps with some degree of accuracy, it was decided to send a party to make a geological reconnaissance of the above region and a track-survey of the sea-coast in going to and returning from Cape Henrietta Maria. Mr. D. B. Dowling was entrusted with this work and was instructed to make an instrumental survey of the Equan river, the largest stream in the

Unexplored region.

Instructions.

region above designated, and track-surveys of as many other streams as could be executed; also a similar survey of Sutton Mill lake. He was likewise to make notes on the timber, soil, fauna, flora, climate and other matters in regard to the district. He was assisted by Mr. W. H. Boyd, of the Geological Survey, and attached to his party were Messrs. J. L. Biggar, of Toronto, and T. M. Papineau, of Montreal. Mr. Dowling reports as follows on the season's work:—

Assistants.

I left Ottawa May 30 and proceeded to Missinaibi, on the Canadian Pacific railway, to which the canoes had been shipped. In order to forward our supplies a 'half-size' bark canoe was obtained and four Indians were engaged to go as far as Moose Factory. As Mr. A. P. Low was going down the river at the same time, we travelled in company, and arrived at Moose Factory on the 17th of June. While there I hired a small sail-boat to carry us and our supplies to the mouth of the Equan river. Heavy north winds, which carried a large ice-floe into the bay, delayed us several days, but we managed to reach the mouth of the Albany river in safety, although we were enveloped in fog and rain most of the time. As directed by your instructions, I looked for gypsum between Moose Factory and Fort Albany, and found some loose pieces of it in the vicinity of Nomansland. It is quite likely that this mineral occurs *in situ* in the vicinity. After our experience in sailing along a shallow uncharted shore, I determined on securing, if possible, a guide at Fort Albany who would know the shore to the north, especially that part near the Equan or Ekwan river. Many of the Indians trading at Albany were from the region we were going to visit, and much useful information was obtained from them. One of their number (Patrick Spence), who lived on the coast near the mouth of the Equan, was hired as guide. After about five days of fruitless endeavour against a head wind, during which we made only about ten miles, we had a day of fair wind from the east and south which enabled us to run to the Equan river, arriving on the evening of July 8.

Moose Factory to Equan river.

Survey of Equan river.

As the Indians of this district cannot obtain bark to build canoes, they were poorly equipped in this respect, and finding that no canoes could be had, we did not divide our party, but with our two wooden ones began a micrometer survey of the Equan. This was continued for about one hundred and fifty miles from the coast, or to the mouth of Washagami river, which I ascertained to be in latitude 53° 48′ 52″. We then ascended this branch to the first lake, from which, by a series of long portages eastward, we reached a small stream that carried us to the south end of Sutton Mill lake. This lake we found to be in a deep valley trending north and south, with an average width of little over half a mile. It is divided into two sections by a ridge of rock, consisting of horizontal beds of Cambrian age surmounted by a heavy trap overflow, similar in general appearance to those of Lake Superior. Through this, by a series of parallel faults, a narrow chasm, nearly blocked up by detritus from the cliffs, allows a small stream to flow from the southern to the northern part of the lake. A log-survey of this lake was made, and while I remained to complete this work and examine the rocks, Mr. Boyd was sent down the stream draining from its northern end, called Trout river, to make a traverse of its course to Hudson Bay. While at its mouth, besides latitude observations, he took a series of barometer readings by which to check the elevation of the lake.

Traverse on shore of James bay.

As the navigation along the Hudson bay shore from Trout river was reported difficult and dangerous, we both returned by the routes we had already traversed, arriving from the interior at the mouth of the Equan on August 22. Having but a short time to spend in this vicinity, I determined on making a quick trip northward along the shore as far as the weather would permit. A log-survey, checked by latitude observations, was made as far as the Opinnagow river. After being detained there by a storm from the north, and fearing a continuance of bad weather, we turned back on August 30, and arrived at the Equan again on September 3. Hiring our former guide, we started in the boat for Albany, but were detained by head wind at the southern mouth of the Attawapiskat river. A latitude observation which we took here confirms the position determined in 1886 by Dr. R. Bell which was questioned at that time, as it was much farther south than that given on the old maps and charts.

On September 6, we entered the Albany river on our return journey and paid off our guide. A storm from the north set in just after we arrived there. When we were ready to start, it had expended much of its force and by the moderated wind we were carried about half way to Moose river. A period of calm weather with light south and south-west winds then set in and we reached Moose river on the evening of September 11. The tide was running out, so we waited till 9 p.m. for it to turn and then we beat in to the Inner Ships Hole by 10.30 p.m. In the afternoon we saw the barque 'Hans,' a chartered vessel, leaving on her run out of the bay. The Hudson's Bay Company's vessel, the 'Lady Head' was still at anchor in the river, ready to start, but she did not leave till about September 15.

Return by Moose river.

The Moose river we found to be very low, but before we left for the south a heavy rain set in for three days, for which we were thankful, as the delay at Moose Factory would be balanced by an increase in the depth of the river which would facilitate our travelling. On the 18th, we left Moose Factory, but soon found that we were obliged to wade for long distances in the shallow water. Owing to the very dry summer, a forest fire had been raging in the valley during the latter part of August and up to the middle of September. This was found to extend from the mouth of the Mattagami river south-westward on the Missinaibie to the Skunk islands. My instructions directed me to make a track-survey, if possible, of the Opazatika river when on my way home; but as this stream flows through part of this burnt area it was especially shallow, and we were satisfied that our canoes could not be got up it without very heavy labour and a loss of more time than we could afford, so we returned by the Missinaibi, arriving at the railway on October 15.

General description of mouth of Moose river.

The delta at the mouth of the Moose river is divided into three channels which enter James Bay. The northern one runs from north of Middleboro island to the north-west of Ship Sands, but it is nearly dry at low water and is also impeded by large boulders, so that it is not used except by canoes and small boats. The southern channel is also reported to be shallow. The central channel which runs along the south edge of the Ship Sands, shoals to seven feet at low tide, and vessels pass at high water after being lightened to draw about twelve feet.

Moose river to Albany river.

Northward from the outer bar to North point, the water is very shoal but it deepens slightly to Nomansland. The low-tide flats are not very wide but the bars project from many of the points for long distances at Long Ridge point and Cockispenny point. At Halfway point, limestone fragments are pushed up along the shore from rock apparently *in situ* below tide. Long Ridge point is built up mostly of gravel with a few boulders showing on the surface. From Nomansland to Albany river the shore is very flat and at low tide the mud flats extend out for several miles.

Mouth of Albany river.

The Albany river, like the Moose, is divided at its mouth into three channels. The trading establishment and mission are situated on an island on the north side of the southern channel. North of this island is the broad opening called locally North river. This has at its mouth a long bar similar in position to the Ship Sands at Moose. The southern entrance to this is the larger, and its entrance seems to be much deeper than the channel going to the settlement. The small channel north of the bar is shallow at low water and has a bar outside on which we found a depth, at high tide, of very little over one fathom. Very shoal water, in which boulders appear, extends northward beyond Nottashay point and boats are obliged to keep nearly out of sight of land to escape the shoals. Chickney river, which enters north of the Albany, is said to be another channel from the latter.

Coast northward.

Shoals were observed, well out from shore to near the Kaypuskow river. In the inner water between Akimiski ('Agoomska') island and the mainland there seems to be a maximum depth of about two fathoms. This shoals gradually to one fathom at a distance of three miles from either shore, as observed in tacking back and forth in latitude 52° 54′ 0″. The mainland here is generally without a beach and between the woods and the tide-line is a wide flat covered with grass. The north-western part of Akimiski island approaches the mainland much closer than is shown on the maps and a number of shoals are scattered from this point to the point south of the Equan river. The boat channel, according to our guide, runs to the west of the two islands which here lie off the shore. The position of the mouth of the Equan river according to several observations is in latitude 53° 14′ 0″.

Northward from the Equan, the shore, for a long distance, is flanked by high gravel bars, but at low tides a broad belt of mud extends out several miles, so that travelling along this coast with canoes is very unpleasant, should the time of high water be in the middle of the day or night. Landing on the beach without a long 'carry' through the mud is only possible at high tide.

Streams south of the cape.

The rivers that enter the bay between Equan point and Cape Henrietta Maria are not large and, as the former maps are mere sketches, it is difficult to locate those which are not known by a local Indian name. The first stream north of the Equan is a small channel said to be a branch from that river. It is marked by two gravel bars to the north about a mile from the beach. Swan river, which is perhaps Raft river of the map, enters in latitude 53° 36′. It is in a slight bay or curve in the shore line. In latitude 54°, the shore takes a curve to the west, forming a point and as the tree-line curves to the north-west from here, this is probably Point Mourning, the first wooded point south of Cape Henrietta Maria. Several small streams flow into the above bay. The first is called by the Indians, Nowashe river—the next Patchipawapoko — then the largest along this coast, the Opinnagow, followed by the last stream Nikitowasaki, fifteen miles north of the Opinnagow. The latitude of the mouth of Opinnagow river by observation is 54° 12′ 24″.

The bay to the south of Cape Henrietta Maria is shallow and muddy with wide mud flats, but near the extreme eastern end of the cape, the shore is reported to be bolder and limestone beds are said to outcrop at high tide mark. These are probably continuations of those found on the Equan and Attawapiskat rivers to the south-west.

Timber.

The timber along the coast gradually becomes smaller as we go northward and the tree-line recedes from the shore, leaving it finally at the Opinnagow, so that the country behind the cape is more or less an open plain. The shore, where the trees are at a distance from the beach, is generally an even mud slope, covered above high tide with grass, followed by a wide belt of stunted gray willows which look somewhat like the sage bush of the western plains. Behind this, a few isolated spruces of small stature appear before the tree-line is reached. In sailing along this coast, it is impossible to know which way to steer so as to run parallel to the land as nothing is to be seen ahead by which to shape one's course.

Tides.

The tides along this narrow shore are not regular in their amount of rise and fall, which is determined, in a great measure, by the direction and strength of the wind. From Equan river northward, the high tide appears to be about six and a half hours after the moon's meridian passage—the flood and ebb running seven and five hours respectively, while to the south of the shallow ground between Akimiski island and the mainland, the flood comes from the south and is much earlier. High tide at Lowasky river occurs at between two and a half and three hours, and at Albany about the same. The flood tide at Lowasky river runs four hours and the ebb eight. At Albany the flood runs five hours and the ebb seven. At the outer bar at Moose river the tides are from half an hour to an hour earlier.

Equan river.

The general course of the Equan river, from the junction of the Washagami or Clearwater river is toward the east-south-east. It emerges from a plateau above the mouth of the Little Equan river, in a wide old valley and then flows eastward over a sloping plain to the sea. In the latter part of its course, it is cutting down a new valley through marine clays which cover the underlying rocks to a depth varying from twenty to fifty feet. From the lowest rock exposure to the sea, the current is swift and it is constantly moving a large quantity of gravel towards its mouth and into the bay, into which the stream empties. Shoals and gravel islands at its mouth bear evidence of this transportation. Nearly horizontal limestones are met at intervals in the section which lies between the fortieth and one hundredth mile from the sea. From a series of fossils collected in these rocks, it would appear that they are older than the Devonian and are probably of Silurian age.

Above the Little Equan, as noted before, the river issues into a wide valley from a higher plateau, but this valley gradually narrows before the Washagami is reached, and cut-banks of clay, higher but somewhat similar to those in the river below, occur at many of the bends. These clays contain marine shells such as *Saxicava rugosa*, *Macoma calcaria*, *Mya truncata* and *Cardium ciliatum*. These were also found at the highest point at which the clays were seen, about 390 feet above tide. The fall in the river from the mouth of the Washagami, as given by our barometer readings, is about 290 feet. North of this to beyond Sutton Mill lake, is a plateau at an elevation of nearly 400 feet above tide, through which, in latitude 54° 20′ rounded or oval domes of trap protrude to a height of from fifty to one hundred feet. Through the plateau, a deep narrow valley has been eroded in a north and south direction, which is now occupied by the waters of Sutton Mill lake. At the lake, the surface of the clay plain is 390 feet above the sea and the surface of the water is 290 feet above the same level.

Marine clay.

Soundings show that the bottom of the southern part of the lake is 310 feet below the plain and that of the northern part 250 feet below the same surface. It was known from the map published long ago by Arrowsmith that a tract of high and broken ground (compared with the generally level country) existed to the south-west of Cape Henrietta Maria. This tract had been assumed to be Laurentian and it was so coloured on former geological maps, but in my instructions from Dr. Bell he predicted that the rocks of this area would more likely prove to belong to the same series as those of the Manitounuck and Nastapoka islands, on the east side of Hudson Bay, which are of the same age as the Animikie of Lake Superior; and my examinations of the region proved this surmise to be correct.

Elevation of marine plateau.

Silurian limestone is found on Trout river, draining Sutton Mill lake, as well as in the bed of this lake just north of the trap rocks The rocks at the narrows of the lake, described on the maps as 'high and romantic,' are cliffs one hundred and fifty feet in height of trap, capping horizontal beds of probably Animikie age. The trap overflow covers the uneven surface of these rocks, in much the same manner as at Nipigon bay on Lake Superior. The underlying rocks are dark slates impregnated with iron ore and interbanded with beds of jasper. Some of the beds seem to contain a high percentage of magnetite and hematite. On the east shore a section of about ninety feet of these jasper and iron-bearing slates is exposed above the lake, but on the west side they have been brought down to below the water level by a series of north and south faults and the exposures there are of the trap alone. These rocks form an east and west ridge reaching to the upper lakes on the Washagami and eastward to a large lake on a

Rocks of Sutton Mill

Iron ores.

branch of the Trout river which, as before stated, drains Sutton Mill lake and runs to the north.

The slates and jasper, or jaspillite, beds form a long anticline, whose axis runs east-and-west and the majority of the beds exposed belong to the northern slope of the anticline. This ridge is terminated on the lake by a series of north-and-south faults with downthrow to the west of unknown amount. The overflow of trap appears to have been at a later date, as there seems to be some unconformity at the base of the trap, the flow having filled all the inequalities in the underlying surface. The cliff at the west side of the narrows is of trap, one hundred and fifty feet high, with none of the jaspillites showing beneath it. On the east side, however, ninety feet of these beds are exposed with a varying thickness of trap above them.

Section.

The following rough enumeration of the arrangement of the beds below the trap is given, but as no careful examination of the rocks has been made, it is to be considered as only provisional:

At the top, in contact with the under surface of the trap, is a series of black, gray, and greenish slates with many of the upper beds impregnated with magnetite. At eighteen feet down, red jasper streaks begin to appear and the first narrow band is quite crystalline, so much so, that it resembles an eruptive porphyry. In the next two feet, very thin beds or streaks of jasper are interleaved with the slates, but they become much thicker below. The jasper beds are seen to be made up of minute oval and rounded concretions of bright jasper separated by a matrix of chalcedonic quartz. As the colour depends on the percentage of these jasper pellets the colour of the beds ranges from light-red to brown. Thin bedded dark rusty rocks form the majority of the beds to about thirty feet down, where several heavy beds of jasper occur. Below this to forty feet, the beds are mostly of dark grayish and black semi-crystalline rocks with fewer red streaks, but they are more heavily charged with magnetite than those above, and some of the thin beds appear to be wholly of magnetite. A covering of talus conceals the slope to about seventy feet down. but, in this space, fragments which lie about, indicate dark iron-bearing slates or quartzites of high specific gravity. In the lower part of the section, the rocks are of a coarser crystalline apparance and the lowest bed, or that exposed at the water level, is heavy with magnetite.

Trout river.

The valley of Sutton Mill lake widens out at the north and its discharge flows at first in an old wide valley and then gradually forms a newer channel for itself. In going north, the timber gets small and disappears before the shore of Hudson bay is reached. The mouth of this river is placed by several latitude observations by Mr. Boyd at 55° 16′ 09″.

Interior.

Along the streams there is a narrow fringe of timber, but in approaching the tree-limit this becomes very small. Back from the immediate slopes of the rivers the surface is nearly level and moss-covered, with scattered groups of small spruce and tamarack. The greater part of the interior is reported to be muskeg (open bog). A small collection of about forty species of shore plants was made at the mouths of the Equan and Albany rivers.

Game.

The principal fur-bearing animals of this district are foxes, otters and beavers. Of the larger mammals, few appear to be obtained by the Indians. In the interior the game birds are all very scarce, the fall hunt for ducks and geese being confined to the shores of the bay. The rivers afford a small supply of whitefish. The streams running to the north into Hudson bay in this region are, at certain seasons, well stocked with speckled trout. Sutton Mill lake is well supplied with a slender variety of lake trout and at the narrows, speckled trout were also caught.

WESTERN PART OF THE ABITIBI REGION.

Mr. W. J. Wilson.

I beg leave to submit the following report of my explorations in the vicinity of Lake Abitibi, Nipissing District, Ontario, during the past summer.

Instructions.

I received instructions from you 'to determine the extent, etc. of the Huronian rocks to the north-west and north of Lake Abitibi, along the Abitibi river from the outlet of the lake downward as far as may be necessary, say to the Long Sault rapids or Frederick House river, southward of the lake to explore and make a survey of the Abitibi river which falls in southward of the Post, and of any natural features possible in that region, west as far as Night Hawk lake and south to the Height of Land or Round lake.'

On June 10, I left Ottawa accompanied by Messrs. J. F. E. Johnston of this department, T. A. Davies and H. F. Lambart. We proceeded to Abitibi post by way of Temiskaming lake and the canoe route from Quinze lake to Lake Abitibi, reaching the latter lake on June 23.

Mr. Johnston, following your instructions, made an examination of the country lying to the east of the Interprovincial boundary, and he will report directly to you on the result of his explorations. He was accompanied by Mr. Lambart.

After storing our supplies in the Hudson's Bay Company's warehouse which Mr. Robt. Skene kindly placed at our disposal, and securing a guide, I came south on the canoe route, over which I had just passed, for the purpose of examining the country south of Lake Abitibi. Maps of this region represent a river as flowing from the south-west and joining the stream flowing from Agotawekami lake, a short distance north of the latter. The Indians told me there was no river there, and subsequent investigation proved this information correct. In passing along the canoe route, the opening looks exactly like the mouth of a river, but it is only a long winding arm, and has not even a small stream flowing into it. Abitibi river, therefore, flows directly from Agotawekami lake. It receives two small streams from the west, about three and five miles long respectively, but they are not passable for canoes except in very high water.

Abitibi river south of lake.

I learned from the Indians that there is a canoe route west from Obadowagashing lake through a series of rivers, lakes and portages round to Agotawekami lake.

Beginning at the north-west bay of Obadowagashing lake, I followed the river flowing from Labyrinth lake a distance of about four miles. There are two short portages on this river and several exposures of a hard fine-grained greenstone containing, in most places, small grains of pyrite. There are also two small exposures of vitreous tuff. Close to the river, the banks are low and are composed of clay, but a short distance back the land rises in low undulations to a height of 50 to 100 feet. The country is thickly wooded with spruce (*Picea alba* and *P. nigra*), poplar (*Populus tremuloides* and *P. balsamifera*), balsam or fir (*Abiès balsamea*), canoe-birch (*Betula papyrifera*), cedar (*Thuya occidentalis*), tamarack (*Larix Americana*), pine (*Pinus Strobus*, *P. resinosa*, *P. Banksiana*), and numerous shrubs, as alder, willow, American yew, mountain maple (*Acer spicatum*), rowan, sweet gale and a great variety of small flowering plants and ferns.

Canoe route west from Obadowagashing lake.

Forest growth.

Labyrinth lake is irregular in shape, about four miles long and three broad. It contains numerous islands which are well wooded but rough and rocky, the rock being compact greenstone containing small quartz veins holding pyrite. Wherever the rock is exposed, especially near the water level, it is polished smooth and heavily striated. The course generally is south to S. 20° W., with stossing on the north. A few granite boulders were noted but no boulder clay. The Indian name of this lake is Kwaskonadaga.

Labyrinth lake.

Continuing the survey westward, I passed through a low marshy river for two miles, then through a small grassy lake called Waterhen lake, then for a mile and a half up a river where a portage of nearly a mile leads into a lake called Wawagoshe, and from this a portage of a quarter of a mile passes over the Height of Land to the head waters of the Blanche river. The elevation where the line crosses the Height of Land is about 980 feet above sea level (aneroid). In passing over the portage into Wawagoshe lake, I noted some comparatively large trees, especially spruce and poplar. Some of the spruce measured sixty-seven inches in circumference, but west of the middle part of Wawagoshe lake the forest is all second growth, the country having been overrun by fire about thirty years ago.

Height of land.

The branch of the Blanche river which forms a part of the canoe route is a very small stream near the Height of Land, but at a distance of a mile and a half it has become twenty feet wide and six feet deep. At a distance of four miles it expands into Snake Island lake, and a mile further into Misemikowish or Beaver House lake. This is a narrow deep lake extending west and north-west seven miles, with an arm running south six miles. The shores are high and rocky, the rocks consisting of massive diorites and schists with numerous small quartz veins holding pyrite. The rock itself contains considerable pyrite in disseminated grains.

Diorites and schists.

Structural lines which may represent the strike run nearly east-and-west with the dip ranging from 75° to vertical. In places, however, the lines run north-and-south. A ridge of dolomitic rock containing iron forms a dam across the south end of the lake, causing a fall of about five feet. The branch of the Blanche river flowing south from this lake is a stream of considerable size, and I was told by the Indian guide that it is twenty to twenty-five miles long. There is a canoe route westward from Misemikowish lake to Round lake, also one leading north across the Height of Land. I followed the latter over a portage of two chains into a narrow lake one mile and a half long, then up a small stream one mile long, two small lakes, a short portage and a lake two miles long to the Height of Land portage. As already noted on Wawagoshe lake the forest growth is all small, consisting chiefly of spruce, canoe-birch, poplar and Banksian pine, the latter eight inches in diameter. This is the character of the forest growth to the south end of the Height of Land portage, where the *brulé* ends, and west probably to Round lake.

Second growth.

A portage of half a mile crosses the Height of Land, then a number of small streams and lakes which form the head waters of the Isabemagussi river were followed for over three miles. Here the canoe route leaves the main stream, which is blocked with driftwood, and a portage of two miles connects with another branch of the river. This I ascended for three miles, when a lake two miles long was reached. From near the north end of this lake a portage of three miles is necessary to again reach the Isabemagussi river, which is now flowing east to Agotawekami lake, about twenty-two miles distant. All the rocks along this route are Huronian, and consist of greenstone and schists, with an occasional band of chert and conglomerate. The latter was seen on the last long portage one mile from the south end; strike N. 70° E.

Huronian conglomerate.

The forest growth is generally heavy and was well seen on the long portages where there are swamps densely wooded with tall, clear spruce ranging from six inches to one foot in diameter. On the higher ground the soil is a deep clay loam and vegetation is very luxuriant. Spruce, twelve to twenty inches in diameter is common, and poplars measuring two feet were seen; canoe-birch and other trees grow to a fair size.

Isabemagussi river.

The Isabemagussi river at the north end of the Three-mile portage, is fifty feet wide and seven feet deep, but the marks on trees, etc., along the banks show that when the ice is moving out, the water is at least ten feet higher than at present, (July 10). The soil along its banks is a sandy bluish-gray, stratified clay, resembling that found everywhere south of Lake Abitibi. The water is muddy, but some of the numerous streams it receives are clear and cold. Very few rock exposures are seen, but wherever they do occur they show the same Huronian strata striking east-and-west. From the appearance of the soil and the luxuriance of the forest growth and vegetation generally, it is clear there is a large area of excellent land for agricultural purposes on this river and its branches, also considerable quantities of pulpwood and saw-logs.

I next made an examination of the country south of Lake Abitibi, going up the rivers for that purpose. The first river ascended falls into the lake about twelve miles west of the Hudson's Bay Company's post. It is called Madawanasaga because there are two main branches which meet near the lake. For the first five miles there are no rock exposures, the banks being low and in places marshy. The first rock seen in place is a purplish-gray, rusty weathering dolomite, and a short distance farther up the river there is a much altered greenish rock which is changing into serpentine. A similar rock was found four miles further south, and at a rapid where I turned back the ordinary greenstone of the country occurs. This river was surveyed for eleven miles, when it became too small for canoes, but the guide said it extends seven or eight miles farther flowing from the south-west.

Serpentine.

The next river that can be ascended by canoes enters the lake west of the large peninsula called by Mr. M. B. Baker, Cauliflower point. The stream he has named Lightning river, the Indian equivalent being Animikewabid. About six miles from its mouth the river divides into two branches of equal volume, but neither of these can be traversed for more than a mile, as they are blocked by numerous jams of driftwood and fallen trees. The branches extend inland to the south-east about five miles. A little over two miles from the mouth of the river there is an exposure of greenstone holding pyrite in disseminated grains. Near the fork the rock is the ordinary greywacke.

Ghost river.

The last river examined on this shore empties into the lake in the south-west part and has been named Ghost river by Mr. Baker; the Indian name is Manitouskosi. This river is one hundred feet wide at its mouth and flows through a flat, clay country, as far as examined, about eleven miles. It continues several miles farther, flowing through more elevated ground. It also receives a large branch from the west. The only rock seen on this river is a small exposure of greenstone at its mouth. Like the other rivers examined on this shore of the lake, the banks are composed of well stratified clay which contains considerable quantities of sand, making the soil a sandy loam. Near the numerous streams this is of excellent quality, and from the appearance of the ground as seen from the surrounding hills there are large areas of good soil throughout the whole district. There are several hills rising to a height of four to five hundred feet above the level of Lake Abitibi and one or two probably higher, but the country generally is rolling and affords good drainage. Small poplar, spruce and fir are common on the lower ground and sides of hills, and scrubby Banksian pine on the top of the hills, but none of these are of much economic importance.

Stratified clay.

Abitibi river.

I next went down the Abitibi river, which was examined as far as the intersection of Niven's meridian line, below the Long Sault rapids. A micrometer survey was made of it from Niven's line to Speight's tie line, below the Iroquois fall, thus connecting with the micrometer survey made by Mr. Speight from that point eastward to Abitibi post in 1900. The first obstruction is four miles and a half from the lake at Couchiching falls, where the river passes over an altered greenstone in a succession of falls and rapids, the total descent being about 46 feet (aneroid). From this fall to the Iroquois fall there are numerous exposures of rock, all of Huronian age, consisting of greenstone, chloritic schists, and in one place an impure dolomite. These cause several rapids, which are passed by short portages. The strike varies considerably, but in a general way, is nearly east and west. At the Iroquois falls the water has a perpendicular drop of 15 feet or more, and would make an excellent water power. The rock here is massive greenstone, which extends for a mile and a half below the falls; then for two miles it is mixed granite and gneiss, alternating with the more basic rocks. The contact between the Huronian and Laurentian is evidently in this vicinity, but, as in so many other places, there is no sharp line separating them. For the next five or six miles to Buck Deer rapids occasional exposures of granite and gneiss were seen, striking N. 70° to 80° W., dip. S. 10° to 20°, W. $<50°$-$70°$. From the Buck Deer rapids to the head of the Long Sault rapids, a distance of twenty-eight miles, there are no rock exposures, but there are numerous gneiss and granite boulders in the bed of the river and along its banks. Examinations were made on both sides of the river, but no rock was found. The Long Sault rapids are caused by ridges of gneiss which cross the river at this place, and good exposures are seen for over five miles. From this point to the crossing of Niven's meridian line no rock was seen.

Contact between Huronian and Laurentian.

The Abitibi river for the whole distance examined has low banks of stratified, sandy clay, rising above the water level from five to twenty-five feet, but in a few places, as at Buck Deer rapids, the banks are higher and somewhat rugged. The soil close to the river is of good quality, but back some distance it becomes in places wet and swampy. The forest is composed of spruce, poplar, balm of gilead, fir, cedar and numerous shrubs. Close to the river the trees are of a fair size, but soon become much smaller.

An examination was also made of the Mistoogo river, a branch of the Abitibi. It joins the latter from the north about ten miles above the mouth of Black river. Less than a mile from its mouth a ridge of chloritic schist, striking N. 80° W. and dipping N. 10° E. $< 75°$, causes a fall in the river of 18 feet (aneroid). This schist contains small veins of quartz, and Mr. R. W. Colthard says that a picked sample assayed in gold $2.20 per ton.* The low state of the water prevented my going far up this river, and the only rocks met with were schists and greenstone of Huronian age. A day's walk into the woods showed large areas of good soil covered with an abundant vegetation but no rock exposures.

Mistoogo river.

The water of Lake Abitibi is muddy during the whole summer. This is true of all the rivers flowing into it as far as examined, and of Abitibi river. The lake being very shallow, the whitish sediment carried down by the rivers or washed from its own clay banks does not get time to settle, as the wind constantly agitates it. This adds a considerable element of danger to canoeing on any of these waters, as it is impossible to see boulders or other obstructions if only a few inches below the surface. By February the water in the lake becomes clear. Muddy water.

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*Survey and Exploration of Northern Ontario, 1900, p. 45.

I next ascended the Black river, the largest branch of the Abitibi, above Frederick House river. Its mouth is twenty-nine miles below the lake and its water, being dark and comparatively free from muddy sediment, contrasts strongly with that of the Abitibi. A micrometer survey was made of this river for forty-nine miles and a track-survey for some distance farther. The river at its mouth is about three chains wide with little current and continues about the same width for about seventeen miles to the first fall. In this distance only two small exposures of rock are seen, both greenstone holding pyrite. About seven miles up the river a stream enters from the east. A portage from near what is called Old Woman rock on the Abitibi river, connects with this branch passing through a small lake. This route is only used by Indians when hunting, as the portages are very long. Nine miles from the mouth, the forest was destroyed by fire four years ago, and for about five miles there is nothing standing but dry stumps of trees, with an occasional clump of green trees along the river and in swamps. The burnt area extends eastward about ten miles, but I did not learn how far to the west. Black river. Burnt area.

The fall above referred to is over a massive greenstone with numerous veinlets of quartz and disseminated grains of pyrite. The total descent here is about fifteen feet and the fall would make an excellent water power. A half-breed family named McDougall have a neat house and small clearing at this point, where they have planted a patch of potatoes which promised an abundant crop. An average stalk measured forty-two inches in length and some of the potatoes were quite large.

The following is a report on soil collected at the above place. Latitude about 48° 38′ and Longitude about 80° 27′.

'A sandy loam of a dark grey colour and showing a considerable amount of vegetable fibre, from fragments of roots and bark chiefly. There are no pebbles and the soil appears to be in an excellent mechanical condition, due no doubt chiefly to its comparatively speaking, large proportion of vegetable matter. Analysis o. Soil

Analysis of the above Soil (air dried).

Moisture	1·86
Organic and volatile matter	9·73
Insoluble residue (clay and sand)	79·96
Oxide of iron and alumina	7·67
Lime	0·45
Magnesia	0·44
Potash	0·36
Phosphoric acid	0·11
Carbonic acid, etc. (undetermined)	
	100·58
Nitrogen, inorganic matter	0·227

Available Constituents.

A determination of the amounts of phosphoric acid, potash and lime, soluble in a 1-per cent solution of citric acid, and consequently to be considered as more or less immediately available for plant use, yielded the following data :—

	Per cent.
Phosphoric acid	·0192
Potash	·0142
Lime	·376

This soil appears to be very well supplied in all the essential elements of fertility, save phosphoric acid—which latter is somewhat below the average found in our better and more fertile soils. In humus and nitrogen it may be said to be particularly rich, though no doubt much of the latter is not present in a condition immediately available to plants. Considered from the physical as well as the chemical standpoint, I should expect this soil would prove one of very fair productiveness, provided climatic conditions were favourable.

FRANK T. SHUTT, M.A., F.C.S.,
Chemist, Dominion Experimental Farms.

Huronian rocks.

In ascending the river for the next eighteen miles, there are many exposures of Huronian rock, mostly massive greenstone and schists. These rocks are generally pyritous, and they also contain many small veins of quartz and epidote. At the second portage there is a dyke-like mass of hornblende granite with green schists on both sides, and at the fifth portage, twenty-nine miles up the river, there is a mass of greenish breccia. These rocks frequently cross the river in ridges and cause falls and rapids, necessitating altogether eight portages in the first thirty-five miles. In this distance the rise is about 150 feet (aneroid). At the seventh portage, thirty-two miles up, there is a fall of forty-six feet, and thirty-five feet of this is an almost perpendicular fall at the head of the portage. This could be utilized for a water power. At the eighth portage, three miles farther up, the descent is thirty-five feet, the chief part of this being over a series of cascades at the upper end of the portage. For seventeen miles above the eighth portage, the river flows through a flat country showing few rock exposures, and there is no further obstruction to navigation in that distance. Several branches of considerable size flow into the main stream in this stretch, and the river beyond becomes gradually smaller. Fifty-two miles from its mouth where we turned back, it is twenty-five feet wide but too shallow to float an empty canoe (August 29). It was also blocked at short intervals with fallen trees. The Indian guide informed me that the river continues eastward for about fifteen miles with numerous branches; also, that at about half this distance there is a perpendicular fall much higher than any we had passed.

The country round the head waters of Black river.

Near the fifty-second mile I ascended a bare hill 120 feet high, from which an unobstructed view of the surrounding country was obtained. To the north, north-west and west, it is comparatively level with an occasional hill rising 100 feet above the general surface. To the north-east, east and south, the country is much more rugged. There are several bare rocky hills within a radius of four or five miles, while in the distance, much higher blue peaks appear. All the rocks seen in these hills are Huronian greenstone, striking N. 45° E., dip S. 45° W. < 70°. The forest, as seen from this hill, is all second growth, except an occasional clump of trees that escaped the fire which swept over this region thirty years ago. The northern boundary of the burnt district crosses the Black river about thirty-three miles from its mouth, and extends southward beyond the Height-of-Land and eastward close to the head waters of the Isabemagussi river, and, I presume, connects with a similar second growth already mentioned as occurring on Misemikowish lake and vicinity. The Indians did not know how far the burnt area reached to the west, but said it was a long distance. Canoe-birch and poplar, from one to four inches in diameter, are most common, while small spruce, fir and many shrubs are abundant, with Banksian pine on the rocky hills and sandy ridges. Along the Black river the areas which escaped the fires are covered by a heavy growth of spruce and poplar, which will yield a large quantity of saw-logs and pulpwood. The soil along the river is a clay loam of excellent quality, and as far as could be learnt, it extends over portions of the lower part of the whole district. There are, however, many swamps and sand plains.

Good soil.

Route to Round lake.

The route south to Round lake leaves the Black river forty-one miles from its mouth and follows a winding branch, White Clay river, to Kékékwabik lake and thence to the Height-of-Land through small streams, lakes and portages. The stream, which I have called White Clay river, is known by a long Indian name which means 'flowing through white clay.' The name is very appropriate, as the soil is composed of a whitish clay, mixed with a large quantity of sand. Three miles from Black river there is a fall of twenty feet over greenstone dipping S. 80° E. $<10°-15°$. The fall is passed by a short portage on the west side. There are two more portages before reaching Kékékwabik lake with exposures of rock of Huronian age. This lake is six miles south of Black river, in a straight line, but following the sinuosities of the stream, it is more than eight miles. On the west shore of this lake there is a steep rock composed of breccia-conglomerate. The matrix is of a dark green colour and the pebbles are granite, quartz and many small fragments much resembling the mass of the rock. They are angular, sub-angular and rounded, and vary from the size of a pea to 20 inches in diameter. Nearly half a mile south of the steep rock above referred to, a reddish-brown breccia-conglomerate occurs, and this gradually merges into the more common greenish variety. On the east shore near the north end the ordinary greenstone is seen and a little to the south, a beautiful quartzite or arkose rock occurs, and near the south end of the lake there is a reddish coarse felspathic agglomerate. On a small lake a few chains west of Kékékwabik lake and parallel to it, breccia-conglomerate again occurs similar to that already described at the steep rock. The dip is N. 70° W. at a high angle. On a small lake, a mile to the east, there is an exposure of a very fine black fissile slate. Strike N.W., dip vertical. Continuing south, the river for about a mile is deep and sluggish flowing through a marsh. Here a stream enters from the west draining Swan and Gull lakes. To the south the stream was so small at that season (Sept.) that we had to carry the canoes and luggage most of the way to the Height-of-Land. After crossing three portages and two small lakes, a branch of the Blanche river, flowing from Sasakinaka lake was reached. I followed this stream to Kinogami lake and thence to Round lake, making a track-survey to the former and a micrometer survey of the remaining distance. Between Kékékwabik lake and Kinogami, the rocks are all Huronian greenstones, schists and slates striking nearly east-and-west. The soil is poor, except some small areas along the river, and the forest growth is valueless from an economic standpoint, as it is all small second growth. Kinogami lake is over five miles long and one mile broad. Huronian rocks, consisting of a fine-grained greenstone, breccia-conglomerate and reddish quartzite, are seen at different points along its shores. Five miles east of Kinogami lake, in a straight line, or seven and a half by the river,

Breccia conglomerate.

Blanche river.

Kinogami lake.

at the first portage, there is an exposure of conglomerate containing jasper pebbles. There is also a band of dolomite fifteen inches wide, holding a considerable quantity of iron. Strike N. 75° E., dip vertical. A mile and a half farther down there is a lake a mile long known as Kapikokonaka lake. From this a portage of nearly a mile is necessary to avoid rapids and beyond this there is no further obstruction, except from fallen trees and driftwood. Three miles and a half north of Round lake, in a straight line, there is an exposure of a hard reddish syenitic rock composed chiefly of felspar and hornblende; the same rock is seen at several places farther down the river and the last outcrop is only a short distance above the lake. The dip is S. 10° E. < 60°. The river where it enters Round lake is a chain wide, and the lower part is comparatively straight with clay banks and some good land.

Syenitic rock.

I returned to the northern part of Otto township and made a track-survey of a small winding river flowing into the Blanche, seven miles north of Round lake. This stream drains a large number of lakes; the largest, called Anikojigami, is four miles from its mouth. The rocks up to this lake are greenstone and breccia-conglomerate, holding jasper pebbles. The latter rock is well seen at the fourth and fifth portages, where the matrix is of the ordinary dark-green colour and the pebbles are abundant and varied, being mostly well rounded. In fact some of the rock is composed chiefly of pebbles, with just enough of the matrix to hold them together. The pebbles consist of granite, quartzite, greenstone and jasper. On one small surface I counted seven jasper pebbles some two inches in diameter. The strike is N. 20° E.; dip vertical. The hills rise to a considerable height on both sides of this river, but slope gradually back. The banks, where not rocky, are composed of a whitish sandy clay. Anikojigami lake, as its name implies, is a collection of lakes joined together by narrow passages. It is more than eight miles long, with narrow winding arms. The shores are usually high and rocky, with a stunted second growth of poplar, canoe-birch, Banksian pine, etc. The rocks are the ordinary Huronian greenstone and schists, as are all those on a number of small lakes to the east and north. Eastward there is a canoe route to Misemikowish lake, which I followed four miles, making a track-survey. The last lake examined on this route is called Kaminamekoka, and is a beautiful sheet of water over two miles long. The height of land is one mile and a quarter directly north of Anikojigami lake, where there is a small lake from which the water flows both north and south. We followed the stream flowing north to Kawanaska lake, from which a stream flows directly to Black river.

Jasper conglomerate.

Height of land.

Sasakinaka lake.

Coming back to the southern part of Anikojigami lake, a canoe route was surveyed to the west, coming out where we first reached the Blanche river on our way to Round lake. There are four lakes on this route and as many portages. The largest lake, called Sasakinaka, is three and a half miles long and full of islands clustered together. On the first small lake west of Anikojigami there is an outcrop of a granitic rock, and exposures of the same rock occur for nearly two miles west. The strike is N. 70° E. Huronian rocks are found elsewhere on this route. Some areas have escaped the fire of thirty years ago and these are covered with a heavy growth of spruce, poplar, canoe-birch, fir, red pine and red maple *(Acer rubrum)*. This is the only place I have seen the red maple in the whole district.

I returned to Abitibi post and spent some time in trying to make an examination of the north shore of Lake Abitibi and the rivers flowing into it from that side, but owing to heavy storms and high winds, I found it impossible to accomplish much. This shore has, however, been examined and well described by Mr. Walter McOuat* of this Survey and others.†

Indian relics.

On Lower Lake Abitibi, at the east end of the portage, across the peninsula from the south, I found a number of interesting Indian relics. They were lying on the sandy beach, covered at ordinary high water, and consisted of several pieces of pottery, showing five or six different patterns of ornamentation, part of an arrow head, several knives and scrapers, gun flints, a stone axe and numerous flint chips. The pottery seems to have been made from the clay and sand contained in the bank at this point. Close to the bank there are hard baked, irregular masses four or five inches thick which seem to be of the same material as the pottery. Stone knives and scrapers were also found on Black river at the mouth of White Clay river and on a point in the southern part of Agotawekami lake, and a perfect arrow head on Kapikokonaka lake, in Otto township.

Glaciation.

The whole country examined shows evidence of heavy glaciation. This is seen in the transportation of boulders, the general rounded appearance of the hills, and especially in the smooth, polished and striated rock surfaces so frequently met with. The latter are best seen in the lakes, on the shores of islands and on rock exposures in the rivers at or near water level. When the rock is wholly exposed to atmospheric action the surface has been so changed by weathering that striæ are rarely preserved, but when the surface is covered for a portion of the year, the glacial grooves and lines are very distinct. There are two general courses. The latest, which is by far the most common, varies from S. to S. 20° E. ast. and an older set runinng from S. 20° W. to S. 35° W. ast. That the direction of the ice movement was from north to south over the Height-of-Land, there is most conclusive evidence. The stossing is invariably on the north side, as is well seen on the islands in Abitibi and many other lakes. Many buff-coloured limestone boulders, similar in composition and colour to the rock occurring north of the Sextant rapid, sixty miles from Moose Factory, were found on Lake Abitibi, and also at the Long Sault rapids. These boulders contain typical Devonian corals and they were evidently carried by the ice from the above mentioned Devonian strata.

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*Report of Progress Geol. Surv. Can., 1872-73, pp. 126, 127.

†Report of the Survey and Exploration of Northern Ontario, pp. 46-48

Boulders containing Devonian fossils.

The whole country examined is frequented by fur-bearing animals, which form a means of livelihood for the Indians. Each Indian has his own hunting-ground and it is said they are careful not to trespass on each other's property. A good hunter will secure furs to the value of $400 in one winter, but many do not exceed $200. The animals hunted are moose, caribou, Virginia deer, bear, fox, wolf, muskrat, marten, lynx, otter, weasel, beaver, mink, ermine, skunk, porcupine, fisher, and rabbit. Moose were very plentiful about the head waters of the Blanche and Black rivers, especially the former. Fresh tracks were frequently seen in the soft mud along the streams and their paths were common and well beaten through the bush. The Indians say that the wolves are increasing alarmingly fast, and they fear if their rapid increase is not checked they will exterminate the deer and other animals. They are sometimes successful in their attacks on the moose, especially the young ones. Fish of various kinds are numerous in all the lakes and rivers, and many species of birds were seen during the summer.

Game.

From my observations in this district, I am convinced that there are large areas of agricultural land of excellent quality, especially in the river valleys, the soil being in most cases a clay loam, free from stones and easily cleared. The climatic conditions also seem favourable for farming operations, and these would improve with the clearing and drainage of the land. Out of a collection of nearly seventy species of plants from this district, Professor Macoun says there is only one which indicates a cold climate and that was found in a peaty swamp. When it is remembered that Lake Abitibi is farther south than the southern boundary of Manitoba it will be seen that there is nothing in the latitude to prevent the successful cultivation of the soil, and further, it has been practically proved for many years that vegetables of all kinds can be successfully grown at Abitibi post.

Rich agricultural land.

Climate.

In the collection of plants above referred to, there is a black-fruited Cratægus, which is probably a new species.

Dead tamarack.

Raspberries and blueberries were frequently met with, though they are not plentiful. High bush cranberries are common along the streams, and the Indians report several bogs where low bush cranberries are abundant. The tamarack is everywhere dead, and though an occasional tree has a few green leaves, I did not see a vigorous one the whole summer. In certain localities a considerable percentage of the spruce is also decaying, and I noted many cedars with the foliage from one-third to one-half dead.

Mr. Skene gave me the following dates as the opening and closing of Lake Abitibi:

Opening.	Closing.
1898, April 11.	October 28.
1899 " 28.	November 11.
1900 " 30.	" 11.
1901 " 11.	(Not received.)

The first frost at the post this fall (1901) was on September 25.

I may state that Mr. T. A. Davies, who accompanied me the whole summer as assistant, did his work in a very efficient and satisfactory manner.

I have to thank Mr. O. E. Taylor, Mattawa; Mr. B. M. Miller, Ville Marie, and Mr. Robert Skene, officers of the Hudson's Bay Company, for much valuable assistance and many kindnesses, especially Mr. Skene, who did everything in his power to aid me in my work.

EASTERN PART OF THE ABITIBI REGION.

Mr. J. F. E. Johnston.

Instructions.

In accordance with your instructions I left Ottawa on June 10, and proceeded in company with Mr. W. J. Wilson to the Hudson's Bay Company's post on Lake Abitibi, this point having been decided upon as the best depot from which to make a geological and topographical examination of that portion of the country lying to the east of the regular Hudson's Bay Company's route from Lac des Quinzes to Abitibi, northward to latitude 48° 45′, and east and south as far as could be got over in the time available.

The post was reached on Sunday, June 23, and the following day was spent in arranging outfit, securing guides, &c. One of the men hired to help us to get our outfit in from Quinze lake to Abitibi and who had been over a considerable portion of the country to be examined, was engaged to act as guide and canoeman. He found, however, that he would be unable to join us for eight or ten days. Accordingly, on the next day, with Mr. H. F. Lambart, of Ottawa, as assistant, and one Indian, I left for a short side trip to Agotawekami lake, to examine any brooks entering on the east side with a view to finding a practicable route into the lakes which had been already surveyed by Mr. John Bignell, P.L.S., of Quebec, on the south-eastern side of the height of land. A good sized brook, coming in one-third of the way down, was ascended to a point where it was found to be completely blocked with fallen timber, and had to be abandoned. I then struck across through the bush to the height of land, but did not find any way to get through with a canoe, nor were any rock exposures encountered. The timber consisted principally of excellent white spruce and poplar, the former having an average diameter of from nine to eighteen inches, while some of the latter was large, a few of the trees having a thickness of two feet near the butt.

Assistant.

Timber.

We then returned to Abitibi to meet the guide and, although we waited a couple of days over the time agreed upon, he failed to appear. We, therefore, secured a small bark canoe and two Indian boys (it being impossible to persuade any of the men to come) and started up the Amikitik or Whitefish river which enters Lake Abitibi at its north-east corner about four miles and a half from the Hudson's Bay Company's post. As this trip was to be over entirely new ground, a micrometer survey was made of the stream and of a good sized lake drained by it. The lake is situated about twenty-eight miles from the mouth of the stream.

Whitefish river.

Whitefish river is a sluggish, dirty brown stream five chains in width at its mouth and varying from three to five chains, up to Makamik lake at its head. It is about twenty-five feet deep at seven miles from its mouth and fifteen feet at two miles below the lake. It is fed by numerous good sized creeks and flows through a flat country. The shores are thickly wooded and low, and the soil along its banks is a good clay loam. In ascending the river, the first break in the smooth water occurs twelve miles up, where there is a chute and rapid with a total fall of about thirteen feet. Three-quarters of a mile further, there is a slight rapid falling one foot and in less than a quarter of a mile another chute and rapid occur with a fall of fifteen feet. Four miles and a quarter further on we came to the biggest rapid and chute on the river with a fall of thirty feet. Two other small rapids occur within the next three miles and a half, with a total fall of about four feet and from this to the lake is dead water.

Huronian.

The first rock exposure met with on the Whitefish river occurs two miles from Abitibi lake and consists of Huronian biotite schist. Three miles higher up is a small exposure of biotite gneiss and from there till Makamik lake is reached, the only rocks met with are altered diabases and mica and chloritic schists, striking in a general way, about east and west. Ancient glacial action is very evident along the river and the striæ are well defined.

Makamik lake.

Makamik lake, at the head of this river, is approximately six miles and a half in its greatest length and its extreme width is about six miles. In general direction it lies nearly north and south with one large bay to the west and two to the east. The water is very shallow and although we sounded it in a good many places, the greatest depth we found was five and a half feet with clay bottom and the high water mark is only three feet above this. The shores are heavily wooded with white spruce, white and black poplar, balsam, white birch, a few black ash and near the water some excellent cedar.

It is fed by three fair sized streams, one of which enters the lake at the extreme southern end (which we afterwards ascended) and two others coming in close together on the eastern shore. The two latter are about 100 and 150 feet in width respectively and possibly are two mouths of the same river. There is also another brook entering the lake on the western shore, called by the Indians Ogassassan; we examined this brook later on. Whitefish river, the outlet, leaves the lake at its most northerly point and flows, in a general way north-west for fifteen miles, then swings round and flows in a southerly direction to Lake Abitibi. The rocks on the northern shore of Makamik lake resemble those on Whitefish river, but on the southern side we found altered granite, biotite schist, granite and gabbro. The general strike is from about east-and-west to north-east and south-west with a northerly and a north-easterly dip respectively. Most of the rocks are well striated.

General course of Whitefish river.

Guides desert.

The morning after completing the survey and examination of Makamik lake, we found on awakening that the two Indian boys had left during the night, taking the bark canoe and leaving us with one shallow 17 foot canoe to carry our whole outfit and three men. This of course prevented me from doing any further micrometer work, but as it was very desirable to reach the head waters of the Whitefish river it was decided to ascend the stream entering at the south end. A time traverse was made of this river and the lakes at its head, carefully checked by astronomical observations for latitude. The magnetic variation was also observed as frequently as possible.

In ascending this river, which is about three chains wide at the mouth, we travelled almost directly south for nearly seven miles, south-easterly for nine miles, when we swung round and travelled a little south of west for over two miles. This brought us to the next lake, which is entered about the middle of its north shore. At the mouth of the river between Makamik lake and this one, there is a peat bog, but its extent is small. The river maintains the same width approximately, to within about three miles of the lake, when it gradually widens to about seven chains, narrowing again to about three chains where it leaves the lake. The water is very muddy at the mouth, but gradually becomes less so higher up and at the head it is comparatively clear. The bottom is clay and the soil on either side clay loam. The shores are well wooded with white spruce, white and black poplar, balsam, tamarack and black ash and a good deal of Banksian pine.

Peat bog.

Several brooks enter on either side, but they are all so choked up with fallen timber that it would be impossible to go up them in a canoe. The first rapid occurred about seven miles and three quarters from the mouth. It was about nine chains long and had a fall of twelve feet. Here there is an exposure of massive gray granite, well striated, and the same rock is seen at the next two rapids, the first of which is a little over a quarter of a mile farther up, falling about five feet and the second seven chains further still, with a fall of fifteen feet. One mile and a quarter more brought us to a fourth rapid falling about six feet and here the rock, which is very much disturbed, is an altered diabase. One more rapid has to be passed before reaching the lake and this is the one of greatest fall. It is about two miles and three-quarters above the last mentioned, and consists of a chute and a rapid about sixteen chains long with a fall, according to the aneroid, of thirty-five feet. The same altered diabase crops out again here. For the last three miles before reaching the lake, the shores are very marshy, covered with alder in places, and occasionally running back into tamarack swamps. Just before reaching the lake, however, the shores become tree-covered to the water's edge and the river narrows again. Our progress up this river was somewhat slow, as all our portages had to be cut out and, having only one Indian and my assistant, this took considerable time.

Exposure of massive gray granite.

The lake at the head of this river is a very pretty one. It is about two miles and a quarter long, half a mile wide, and lies almost exactly east-and-west. The extreme western end and the extreme eastern where the inlet occurs, are somewhat marshy, but the shores of the rest of the lake are wooded to the water's edge with white spruce, white and balsam poplar and cedar. To the west and south-west the ground begins to rise almost from the water's edge, up into the low hills forming the height of land. The depth is ten to twelve feet and altered diabases, striking in a general way east-and-west, are the only rocks met with, except on a small island, a quarter of a mile from the inlet, where a volcanic breccia is exposed containing slate pebbles, pyrite and a pseudomorph probably siderite after pyrite.

Volcanic breccia.

Ascending the inlet, it gradually widens out into another lake of a marshy character for the first mile. It is on the same level as the last lake, and beyond the marsh it is a beautiful sheet of water with a total length of about eight miles and a half and an average width of from half a mile to a mile. Looking up the lake from its outlet the main axis would be a little south of east for seven miles, when it turns sharply to the north, in which direction it continues for a mile and a half further. About the middle it narrows to a quarter of a mile and is studded with islands, some seventy in number. Nearly every point on the lake shows rock exposure. The water is dark in colour but not muddy, and the average depth is about sixteen feet. As I was unable to find any Indian at Abitibi who knew these waters and consequently could get no name for them, we called the lake for descriptive purposes, Lake Lois.

Lake Lois,

There is an exposure of breccia near the western end, and all the other rocks seen are altered diabases and greenstones. The rock is everywhere rounded by glacial action and well striated. The strike varies from about north-east and south-west to east-and-west. The shores are well wooded with the same timber we had seen all along. Two creeks enter the lake at its eastern end and both of these were examined as far up as we could get, but a mile or so from the mouth of each, the water was found to become very shallow and the brooks choked with alder bushes and fallen timber. We then followed their courses by walking through the bush to see if there were any more lakes on this route, but they both seemed to rise merely in marshes or swamps. A quarter of a mile north of the long northerly arm, at the east end of Lake Lois, another small lake was found. Its longer axis trends north-east and south-west; it is a mile and a half long and one-eighth to one-quarter of a mile wide. A portage was cut to the lake, of which a traverse was made. The rocks and the timber on this lake resemble those on Lake Lois. It is ten feet higher than the latter lake and its outlet, which is at the north end, is a very small brook running in the opposite direction from Lake Lois. This satisfied me that Lake Lois is the source of the river emptying into

Makamik lake and is consequently one of the head waters of Whitefish river. We now returned to Abitibi post over the same route by which we came, and on our way examined Ogassasan brook, already mentioned, for a couple of miles, when it became completely choked with wood. One mile and a quarter from its mouth there is a chute falling three feet, and here chloritic schist, striking south-east, is exposed.

Return to Abitibi post.

We reached the post on the evening of August 5, and as Mr. Wilson and myself had agreed to meet August 15, to arrange about going out together at the end of the season, I decided to use the interval in again trying to find a route into the lakes on the south-eastern side of the height of land. Two or three days were lost by very bad weather, but on the 9th we went up to Agotawekami lake and, after a careful search along the east shore we found a brook coming in about four miles above the one we had tried previously, and this proved to be the route required. It is rather difficult to find, as the mouth is hidden in marsh, and at twelve chains up, the brook widens out again into a very shallow marsh, in which the water was so low that we had to pull the canoe through by wading. We followed a number of sections of this brook alternating with marshes, portages and small lakes till we crossed the height of land into Lake Kajakanikamak, which is practically at the same level as the last lake on the Hudson bay side of the watershed. This lake is about one mile and three-quarters long in a general south-easterly direction from the end of the portage, and about one-eighth of a mile wide. A couple of exposures of greywacke were seen and about half way down, one of conglomerate. On completing the examination of this lake I returned to Abitibi to meet Mr. Wilson, and having arranged with him to meet again at Klock's depot on Quinze lake on October 15, I started back to Kajanikamak and continued the exploration to the eastward.

Lake Kajakanikamak.

The lakes in this part to the east and south had been already surveyed by Mr. John Bignell, P.L.S., Quebec, so that the topographical work for the remainder of the season consisted merely of minor track-surveys up small brooks and between lakes previously located.

Lakes surveyed by Mr. John Bignell, P.L.S.

Leaving Kajanikamak lake at its south-eastern end, a little over two miles of very bad brook travelling brought us to Kakameonan lake, which is about six miles in length and varies from half to three-quarters of a mile in width, lying in a general direction north-west and south-east and with a bay near the middle of the north-east shore running north-east for about a mile and a half, out of which it discharges.

Kakameonan lake.

Like all the other lakes in this district, the shores of Kakameonan are well wooded with aspen and balsam-poplar, white spruce, balsam-fir, tamarack and an occasional pine. The rocks seen were greywacke, chert, a breccia with flinty felspathic quartzite pebbles, altered diabases and a hard, compact, light-gray Huronian rock. The brook which is the outlet, joins the west branch of the Kinojevis river about six miles above the junction of the latter with the east branch. Altered diabase is exposed a quarter of a mile up the west branch above the brook, and a mile and a half beyond this slate is seen. Below the outlet of Kakameonan there are no exposures on the west branch which flows over clay and is from sixty to a hundred feet wide. Ascending the east or main branch, which is from three to four chains wide, there is a swift current four miles up, and at five miles altered diabase was seen at a rapid.

Rock exposures.

Several exposures of slate and graywacke were seen before reaching Kabakwobia lake, a small expansion of the river about two miles long. A short stream from the south, a mile long, connects it with Kawbaswakaminikatay, a round marshy lake about a mile in length, and a badly choked creek connects the latter with Kawinakwisakwidaw about four miles to the south-west. About half way up the creek, between the second and third lakes, there is a fall of about eighteen feet with an exposure of chloritic schist. On Kabakwobia lake, schists, slate and greywacke are seen and the shore is well wooded with poplar, spruce, cedar and balsam.

Carcajou river.

In ascending the Kinojevis from the forks, we travelled in a general easterly direction as far as Kabakwobia, then northerly for about four miles when we swung round easterly again. On the river just above this lake there are a few elms, but for some distance after this the river runs through an old *brûlé* with second growth of small white birch and poplar. About twenty miles above Kabakwobia a small stream, known as the Carcajou river, enters from the north, and between Kabakwobia and this stream we passed two more small rapids, the first of which falls about twenty feet and the second two or two and a half feet. The rocks met with along this stretch are greywacke, greenstone and altered diabase holding considerable pyrite disseminated through it in small cubic crystals. We went about three miles up the Carcajou, which is a muddy stream, badly choked in places with fallen timber. Chloritic schist, striking about north-west-by-west is seen on this river at a small rapid. Returning to the Kinojevis, we found that three-quarters of a mile further up, the river forks into two large branches, one known as the Nawapitechin or North river, coming from the north, and the Kewagama from the south.

Forks of Kinojevis river.

North river.

The North river was examined as far up as we could get, a distance of about thirty-five miles. Twelve rapids, all small, varying in fall from one foot to six feet with a total descent of about twenty-seven feet, were passed in this distance, after which the river narrowed to a very small stream choked with alder. The soil is clay-loam and the shores are well wooded the greater part of the way. On the lower part of the river the timber consists principally of spruce and balsam poplar with some aspen. Further up, the poplar becomes scarce and spruce and jack pine are the principal woods. The river is very crooked and in ascending it, the general direction is nearly north-west for two-thirds of the way, when it swings round nearly south for five or six miles and then nearly west again till the end of canoe navigation is reached.

Rock exposures.

The rocks on this river are somewhat varied, greenstone carrying some pyrrhotite and giving indications of the possible presence of nickel, occurring about five miles up the river, while two miles beyond an altered granite is exposed. Within the next mile and a half, greenstone is seen again and also chloritic schist. An outcrop of light-gray altered granite is seen at intervals for about two miles beyond this, and gives place to a very hard cherty rock containing small specks of chalcopyrite associated with greenstone, and further up the river, as far as we managed to ascend, greenstones were the only rocks seen.

Kewagama river.

Having completed the examination of the North river, a return was made to its mouth and we proceeded up the Kewagama some five miles to a lake of the same name. This river flows over clay with good clay loam on its banks, which are well wooded with spruce, balsam and white poplar. There are two rapids, one, about four miles up, with a fall of about six feet, and another near the head falling about fifteen feet. At both of these there are exposures of a rusty, somewhat gneissic biotite schist, striking about north-east.

Kewagama lake.

Kewagama lake, which is much the largest of the different bodies of water examined during the summer, consists of two main parts, an eastern and a western, separated by a long point. The latter runs nearly south almost the whole length of the lake, leaving merely a narrows to join the two parts. The western part is again divided by a second narrows about half way up. The longer axis of the lake would be a line running east and west at its southern end and passing through the first narrows. This would be about eleven miles in length. The extreme width north and south would be about eight miles and a half for the eastern section and nine for the western. The width of the eastern is about six miles at the north end, narrowing to about one mile, half way down and then gradually widening at the southern end to about six miles from the first narrows to the eastern shore.

Diorite, schists and syenite.

Following the shore-line from the outlet round the point dividing the two portions of the lake, a distance of four miles, we met with a coarse-grained diorite, chloritic and biotite schist, and a reddish syenite. A little further on, a soft chloritic schist is exposed, and, about two miles below this, there is a very quartzose altered granite intersected by numerous veins of white translucent quartz of various sizes. Of this quartz several specimens were broken off at random from the top. One of these carrying considerable iron pyrites was assayed under Dr. Hoffmann's direction and gave 0·117 of an ounce of gold to the ton of 2,000 lbs. Others, quite close carried molybdenite and bismuthite. The occurrence of bismuthite is very interesting, as it has previously been found, I believe, in only four localities in Canada.

Economic minerals.

Granite.

Granite is the prevailing rock till the first narrows is reached. There diorite is exposed, and this continues round the point to the second narrows, leading into the northern half of the western section of the lake, and for one mile and a half further. In places, associated with this, is a hard, compact rock carrying considerable pyrites. Quartzose granite is then exposed for some distance, and, about three miles from the head, hornblendic schist. A very marshy creek entering the northern end of this part of the lake, was ascended for about two miles to a small lake at the same level as Kewagama, but no exposures were found.

Returning to Kewagama lake and working along the western shore of this section, mica diorite was seen three miles down, and a quarter of a mile further, chloritic schist. From here to the south end of the lake the rocks are biotite, chloritic and hornblendic schists, with the exception of one point a mile below the narrows, where there is quartzose granite. At the south-eastern corner of this portion of the lake, a river one hundred to one hundred and twenty feet in width enters from the south-west. We ascended this stream for about six miles, passing a little rapid about two miles and a half up, where chloritic schist is exposed. Quite a number of white pine of fair size are seen about two miles up this stream. This brought us to Lake Kai-kaik, which is about four miles long and a quarter of a mile wide. The rocks on this lake are chloritic schists striking east and west, with some slates.

Lake Kai-kaik.

Returning once more to Kewagama we continued the examination of the southern shore, and in a quarter of a mile came to diorite. In the next mile there are several exposures of schist and then one of diorite, then a mile and a half of schist. Beyond the narrows a porphyritic rock occurs, and from here, along the rest of the southern shore, which is very rocky, schist prevails. Along the eastern shore diorites and granites are the only rocks seen, but along the northern, hornblendic schist, granite, altered diabase and, just at the outlet, biotite schist occur. At the north-east corner of the lake, a small brook, about a mile and a half long forms the outlet of a marshy lake called Kapitagama, which is nearly round and about a mile and a half across each way. This lake was also examined, but no exposures were found.

Kewagama lake well timbered.

Kewagama lake is well timbered, fine white spruce and white poplar being very abundant, with a considerable quantity of balsam poplar and white birch. On some of the islands there is a fair quantity of red pine of medium size, and more particularly near the southern portion of the lake an occasional white pine is seen. At some of the narrows and near the mouths of some of the brooks entering the lake there is a considerable growth of small ash, and along the whole lake shore small cedar is seen close to the water.

On completing the examination of Kewagama we returned to Abitibi, as we were out of supplies and time would not permit us to prosecute the work any further to the eastward this season. A route exists from a long bay on the east shore of Kewagama via Lake Newagama over the height of land into a large body of water known as Seal lake.

Lower part of Kinojevis river.

Abitibi was reached September 14, and a day was spent in packing up part of our outfit which was to be taken to Quinze lake by the Hudson's Bay Company. We were further delayed by very bad weather till the morning of the 19th, when we started back to the forks of the Kinojevis, from which point it was intended to extend the work down to the Ottawa river. Proceeding down the river from the forks for thirteen miles, we came to a small lake, after passing two rapids, one being half a mile below the forks and falling about fifteen feet, while the other is about eight miles down and falls three feet. In this interval the general direction of the river is southerly, but it is very crooked.

Numerous exposures occur of chloritic schist, altered diabase, greenstone and a breccia containing flinty, felspathic quartzite pebbles. A number of these rocks carry considerable pyrite and some have very rusty surfaces. A brook enters the little lake from another lake some three miles in length, situated about a quarter of a mile to the west. On both of these lakes, the prevailing rock is greywacke with a nearly

Small lake expansions.

east-and-west strike, and the same rock occurs all along the river with about the same strike for the next seven miles, for four of which the river is flowing east and for three south-west, at the end expanding into another small lake a mile and a half long with a deep bay extending a mile to the south-west; and on this lake the same rock occurs on the upper portion and in the bay. On the lower part of the lake hornblende schist is exposed at intervals for about a mile. The river now runs in two channels for a mile and a quarter round an island, from three-quarters to one mile in breadth, the foot of this island being at the northern end of Lake Kinojevis. We came down the western branch to the lake and saw two exposures of greywacke still striking nearly east and west.

Kinojevis lake.

Kinojevis lake lies for about five miles a little east of south from its head when it makes a sudden turn to the south-west for about thirteen miles, the part below the turn being known as Crooked lake. At the turn the Kinojevis river, its outlet, leaves it and flowing in a general south-easterly direction for about sixteen miles joins the Ottawa river about twenty-one miles above Lake Expanse. Lake Kinojevis with Crooked lake is very narrow, averaging from a quarter to half a mile in width. At its head, on the western shore, a hard biotite schist occurs and on the opposite shore an altered diorite. One mile down, a bay runs for about a mile in a westerly direction and at its head a small creek enters. This we ascended for half a mile, when we came to a lake which is about two miles and a half long and of increasing width till, at the head, it is about a mile and a quarter across.

On this lake we found hard biotite schists, altered diorite, and greywacke. At the western end a brook comes in and going up this a little over two miles, passing an exposure of greywacke on the way, we came to Lake Kekeko. The latter is about six miles long, lies nearly east-and-west, and has two bays at the western end, one running to the north and the other to the south, giving the lake the general appearance of the letter T. Both this and the first lake are practically on the same level as Lake Kinojevis. The first exposure seen on Lake Kekeko is a dark coloured diorite two miles from the outlet and from the point to where the two bays turn off, the rock is entirely slate striking nearly east and west. At the entrance to the northern bay there is diorite and higher up the bay on the east shore, chloritic schist. On the west shore greywacke and slate are the prevailing rocks. At the north end of the north bay a brook enters the lake and we went up it about five miles passing two chutes, one falling ten feet and the other fifteen feet, about one-eighth of a mile apart, and about

Lake Kekeko.

three miles from the mouth. Greywacke, greenstone and chloritic schists are the rocks on this creek. At the south end of the south bay, a small creek comes in from two lakes but the brook was quite impassable for the canoe owing to the abnormally low water. I walked up to the first lake but saw only greywacke. However, it was difficult to do any geological work here as it had been snowing for two days and the rocks were hidden.

Crooked lake.

Returning to Lake Kinojevis we proceeded along the lake and at two miles down found altered diorite, and one mile and a half further rusty biotite schist, and associated with it altered granite. Three-quarters of a mile further we found a hard, black, biotite schist and turning down into Crooked lake the same rusty schist. This rock continues down the lake shore but becomes more gneissic and three miles down is more of a schistose biotite gneiss, striking nearly east-and-west. For the next four miles the same rock occurs, very rusty and decomposed in places, and associated with it is a quartzose granite containing quartz and pegmatite veins. Eight miles down Crooked lake, opposite the mouth of a small stream known as the Kamshigamau river, the same gneiss occurs, in places very micaceous and associated with it everywhere is the same granite, intersected by numerous pegmatite veins carrying considerable muscovite, though from surface showings, only in small crystals.

Descend Kinojevis to Ottawa river.

We now returned up the lake to the outlet at the bend and proceeded down the Kinojevis river. There are two small rapids between Crooked lake and the Ottawa with a fall of a few inches. Schistose biotite gneiss, similar to that seen on Crooked lake, was noted on coming down the river at intervals for about eight miles, after which there are no exposures till about four miles from the mouth, when gray granite, also similar to that on Crooked lake, outcrops. All exposures from this point to the Ottawa river are of granite. The Kinojevis river from Crooked lake down, has an average width of about five chains and the Ottawa river where the latter enters it is about seven chains wide.

Having reached the Ottawa our work for the season was finished and we started at once for Klock's depot on Quinze lake. This was reached on the night of October 14, and Mr. Wilson arriving the next day, we left on the following morning and reached Ottawa on the 20th. During the whole season Mr. H. F. Lambart, of Ottawa, acted as assistant and performed the duties allotted to him very satisfactorily.

Geological conclusions.

The general inference drawn from the rocks in the area examined this season is that the line of contact between the Laurentian and Huronian observed by the late Mr. Walter McOuat in 1872 as crossing

Lake Opasatika on the main Quinze-Abitibi route runs in a general way a little south of east, crossing Crooked lake about the mouth of the Kamshigamau river and thence in about the same direction to the Kinojevis river which it crosses about four miles from its mouth. East of this we had no opportunity of observing it. The most northernly rocks met with were Huronian and the northern limits of the Huronian are extended to cover the whole area examined, the granites mentioned as occurring at different localities being considered as intrusive. The whole area has been subject to glacial action and the rocks are nearly everywhere striated, the grooving being very clearly marked in most places.

Huronian.

Timber.

With regard to the timber—white spruce, aspen, balsam poplar, balsam, white birch, tamarack, Banksian pine, and cedar are the principal trees found. Spruce and aspen are by far the most plentiful and particularly on the northern portions on both sides of the height of land, excellent spruce for pulpwood is seen on the lake and river shores. Balsam-poplar, balsam fir and white birch are probably the next most plentiful, and tamarack is not far behind, but it is nearly all dead, particularly in the northern portion. Cedar is found scattered along the banks of some of the rivers and around the shores of nearly all the lakes. Small ash grows near the mouths of a good many brooks. Small elms are found in a few places and red and white pine occur from Lake Kewagama south, but not in sufficient numbers or of large enough size to be of importance.

Soil.

The soil over the greater portion of the area is a clay loam, changing in places to a somewhat sandy loam, and in some localities would probably make fair farming land if not too wet and cold. Along the river banks it is generally good, and, along the Kewagama river, very good. With reference to this, the conditions at Abitibi post may prove of interest. I was informed by Mr. Skene, the gentleman in charge, that this year the last spring frost at the post was recorded on May 25, and then only one degree. The highest temperature was on July 15, 92° Fahr. and up to September 16 there had been no frost. On June 8 there was a fall of snow, with the thermometer at 36° and in the interval between May 25 and September 16, rain fell on fifteen days.

Vegetables grown.

Mr. Skene has a small garden at the post and has met with complete success in growing the following vegetables, viz., potatoes, onions, cabbages, cauliflowers, beans, radishes, lettuces and cucumbers. They sowed timothy seed in the Company's clearing on May 21, 1900, which yielded an excellent crop of hay the following summer. Oats also gave a good crop.

At the Post the land is well cleared. We did not find the weather in the bush quite so favourable as it was there. Water left in the kettle over night was coated with ice on the morning of September 12. The weather broke this year on September 15, and from that date until we completed our work, on October 15, there were very few days without snow or rain. On Kekeko lake on October 4 and 5, we had a two days snow storm, the snow, twenty-four hours after it had ceased falling, having a depth of three inches. From June 15 till September 14 we found the weather delightful.

Game.

With regard to fish and game, I might say that all the lakes near the height of land on both sides were plentifully stocked with pike, pickerel and suckers. In Makamik lake, however, we found only suckers, while in Whitefish river we caught whitefish, in addition to those mentioned. Farther south black bass can be caught in Crooked lake, and possibly a little above it, but they are very scarce.

Of the larger game, moose are undoubtedly the most plentiful. We saw their tracks often quite fresh all over the area examined, and, although not looking for them during the summer, we saw four of these animals, one on the Carcajou river, two on the outlet of Lake Kai-kaik, and one on Lake Kekeko. We also heard them frequently during the calling season, and the Indians seemed able to go out and get a moose whenever they felt inclined. Caribou are not scarce, but we saw only one, and that had just been shot by an Indian. I saw a black bear on one of the small lakes off Kewagama, and a large lynx on the Nawapitechin river. Of the fur-bearing animals, beaver, otter, marten, muskrat, mink and fisher are common, and of these we saw many individuals. Ermine are rather scarce, but some skins are brought to the post. Rabbits were found to be comparatively abundant. Both the ruffled grouse and spruce partridge are very plentiful, but ducks are rather scarce.

The Sudbury District.

Dr. A. E. Barlow.

Microscopic examination of rocks.

The first part of the year before the commencement of field operations was spent by Dr. A. E. Barlow in a detailed petrographical examination of the various rock types exhibited in the suite of specimens collected to illustrate Mr. R. G. McConnell's work in the Yukon Territory during the seasons of 1898-1899 and 1900. Thin sections were also examined under the microscope of some of the rocks associated with the iron deposits along the Kingston and Pembroke railway. The detailed description of these forms an appendix to Mr. E. D. Ingall's report which has just been issued. Many of the different rock species met with by Dr. Robert Bell and Mr. J. M. Bell in the Great Slave lake and Great Bear lake regions were also sectioned and studied, the results in detail being included in the report covering this work. A considerable amount of petrographic work was also done on the rocks from the Atlin district, the results being handed to Mr. J. C. Gwillim to be included in the final report on this area.

Resumption of work in Sudbury district.

This laboratory work being finished early in June, it was decided to send Dr. Barlow to make any corrections and additions found necessary on the map of the Sudbury mining district issued in 1891. The renewed activity in the mining of nickel in the Sudbury district indicated clearly that the present was a most opportune time to obtain a better knowledge of the nature and extent of those deposits. It was recognized that the geological map needed revision and correction, although its general accuracy and usefulness had never been questioned. Besides, the region had become more accessible by reason of occasional clearances, the opening of roads, and the development and extension of the various mines. Much additional information had likewise been secured concerning these occurrences of nickel, while the advance in geological knowledge due chiefly to the introduction of improved methods for petrographic and geologic research showed how desirable it was to undertake a more thorough study of the geology and petrography of this region.. In carrying out this work, Dr. Barlow was materially aided by Dr. Ludwig Mond, of London, England, under an agreement by which the former was partially relieved from the Survey during the six months from July 1, 1901, to January 1, 1902.

Denison township.

Dr. Barlow was chosen to take charge, not only on account of his former connection with the work, but also because petrography would of necessity enter very largely into any detailed examination and study of these old crystalline rocks. The township of Denison was selected as the starting point, because the work done here in 1890 was more in the nature of a reconnaissance than a finished survey. With a headquarters camp on the west side of Ethel lake, the whole township was carefully and systematically explored, so that the lines of demarcation between the various rocks, as now ascertained and mapped, are very nearly accurate. A month was found necessary to complete the work in this township, after which a move was made to McCharles lake, to the east in the township of Graham. From this base of operations the work was gradually extended over the township of Graham and the southern part of Creighton. The southern limits of the nickel-bearing eruptive was also determined in the township of Snider, and the season was brought to a close in September by certain corrections of a minor nature in the geology of the township of Garson.

Nickel-bearing eruptive.

The investigations of the past summer have shown conclusively that the unaltered normal or type-rock with which the deposits of nickeliferous pyrrhotite and chalcopyrite are associated, possesses rather exceptional character and interest. It belongs to the general family of gabbros, but has nearly always traces of a broad ophitic or diabasic structure, which, although rude at times, is generally quite distinct. The abundance and occasional preponderance of hypersthene or enstatite justifies its classification and description as a norite, while the presence of a considerable quantity of original quartz makes it a rather exceptional rock type. In general, the rock is made up of plagioclase (labradorite or bytownite), hypersthene or enstatite, augite, biotite, hornblende and quartz, with much smaller quantities of apatite, titaniferous magnetite, pyrrhotite, chalcopyrite and pyrite as accessory constituents. In general all the workable deposits of nickeliferous pyrrhotite or chalcopyrite, are situated at or near the borders of bands of this quartz-hypersthene-gabbro or norite.

Mineralogical composition.

Genesis of ore.

It is now confidently believed that these several sulphides which the rock contains were introduced simultaneously and as integral portions of the norite magma. At the same time pneumatolytic or secondary action was taking place on an extended scale and much of the sulphide material has undergone a subsequent rearrangement and consequent local enrichment. It must be understood, however, that the secondary action was proceeding during the slow cooling and differentiation of these immense bodies of norite magma, and that the ore-bodies were acquiring their present position and dimensions during this extremely slow diminution in temperature of the whole mass, so that the final consolidation saw these ore-bodies under very much the same conditions as at present obtain. The brecciated character of many of the ore deposits seems to give emphasis to the fact that autoclastic action has played an important part in the formation of many of these deposits, the sulphides being possibly more susceptible to rearrangement, while the accompanying rocky portions have undergone extensive fracturing and dislocation. Associated with the nickel-bearing norite and passing by insensible gradations into it, is a rock which has been called 'micropegmatite.' This rock, which is closely allied to the granites, must be considered as an integral and differentiated portion of the nickel-bearing eruptive. There is an undoubted and perfect transition from one

Brecciated ore.

rock type to the other. This transition is now well understood. Microscopically, this change consists in the gradual assumption of a reddish colour replacing the green or greenish gray of the rock, this being accompanied by a corresponding increase in the amount of quartz and felspar. The hornblende of the norite is gradually replaced by biotite as the prevailing ferro-magnesian constituent, while orthoclase succeeds plagioclase as the prominent felspathic mineral. Concomitant with this, a decided foliation may be noticed to have been induced, corresponding with the general strike of the band, while micropegmatite or granophyre is very characteristic over large and often widely separated areas.

Nature of transition to norite.

Three belts of norite.

In the Sudbury mining district there are three main belts of these norite and associated micropegmatites. These may be called, respectively, the northern, southern and middle belts. At present they are mapped as distinct and separate, but genetically and mineralogically, they are essentially identical. They likewise belong to the same geological period and are very nearly, if not quite, synchronous. The most northern band starts from the old Ross mine (W.R. 5) near the line between lots 5 and 6 on the line between concession III and IV of the township of Foy, and extends in an east-south-east directicn into the township of Bowell, where, on lot 6, concession II, it branches. One band runs south-west into the townships of Lumsden and Morgan, where its limits have not been ascertained. The other or main band runs on to the east, cutting across the township of Wisner, and crosses the Vermilion river immediately north of Bronson lake. Trending still more to the north it connects with the large area of basic rocks to the west of Lake Wahnapitae. The delineation of this belt is mainly owing to prospectors. The middle band of norite, according to the present state of our knowledge, starts on lot 12, concession III of Trill; extends north and north-east through this township into Cascaden, and crossing under Windy lake, goes on uninterruptedly through the north-west corner of Dowling, to lot 2, concession IV, Levack. There is probably then a considerable break between this and the Ross mine on the northern nickel range on the one hand and the basic band which runs through part of Morgan, but both bands are almost identical in mineralogical composition and are certainly genetic equivalents. It is along the northern contact of this band and the granitite-gneiss to the north that the famous Levack deposits are situated. This band of norite is about eighteen miles long and in places nearly half a mile in width.

Middle band of norite.

Main or southern band.

The most important and famous band of norite, however, is the southern belt, which, starting in more or less isolated patches and areas in the township of Drury, coalesces into one large band in the eastern part of this township. It then extends in unbroken continuity in a north-easterly direction as far as lot 3, con. III of Garson, a distance of over thirty-two miles. The basic or norite portions of this band would average nearly two miles in width throughout its length. In the township of Denison the basic rocks extend over the greater part of the third, fourth, fifth and sixth concessions. About lot 2 the band attains its maximum width of nearly four miles, but a short distance east it is divided up into two belts by the intrusion of a mass of coarse "augen" granitite-gneiss. The northerly, which is the more important of these two belts, has a course of N.N.E. through the north-eastern part of the township of Denison and the south-eastern corner of the township of Fairbank. Thence it extends across the Vermilion river, covering part of the township of Graham and portions of the township of Creighton. From thence it runs across the central part of Snider, through the north-western corner of McKim and the south-eastern part of Blezard and, with the exception of lots 1 and 2, extends continuously across concession III of Garson. Through Creighton and Graham, this belt is over two miles in width, while near the old Dominion mine it is almost three miles from north to south across the norite. The southern branch of this great belt runs across the Vermilion river, covering parts of Graham, and thence on through Waters past Copper Cliff, where it rejoins the other branch. The lenticular mass of granitite-gneiss which divides this southern belt into two portions, thus occupies a strip of country one and a half to two miles wide through Graham and Snider, terminating at or near the Copper Cliff mines. It is newer than the norite, piercing and altering the basic rock.

Two branches.

It is now confidently believed that the nickel and copper deposits of Sudbury are the most important of their kind known in the world. The inauguration of the extensive and well equipped works of the Mond Nickel Company at the Victoria mines, and the extension of the works of the Canadian Copper Company, will rapidly place Sudbury in the foreground of the nickel-producing areas of the world.

Value of deposits.

HALIBURTON AND BANCROFT AREAS, ONTARIO.

Professor Frank D. Adams.

The field-work in the Haliburton and Bancroft areas was very nearly completed during the summer of 1900. The time which could be devoted to the work during the past summer, namely two months and

Field-work by Dr. Adams.

a half, was accordingly spent in finishing the field operations and in beginning the preparation of the report.

Townships covered.

Six weeks were spent in July and August in the examination of the specimens collected during the several summers past and in the preparation of the geological maps of the area, and on August 21, I left Montreal for the field, where I remained until September 24. The field work during the past summer was carried on chiefly in the townships of Monmouth, Glamorgan, Harvey, Burleigh and Dysart. The geological relations in the two former townships are very complex, but were worked out successfully with the aid of the topographical surveys made in this area by Mr. L. N. Richard of the Geological Survey, who accompanied me during a portion of September. The distribution of the nepheline syenite, which occurs abundantly in these townships and which, in the eastern portion of the area embraced by the Haliburton sheet, holds the large deposits of corundum discovered by the Survey and now so extensively worked, was carefully traced out and several new areas of this rock, often containing indications of corundum, were discovered and mapped. The great gabbro area in the southern portions of these townships, which holds the iron ores occurring there, was also surveyed and carefully studied. Great bodies of excellent limestone were also found in the south-western portion of Glamorgan.

Work by L. N. Richard.

Distribution of rocks.

Dysart.

After the completion of this portion of the work, the eastern half of the township of Dysart was examined, in order to determine the limit of the limestones against the granite-gneiss and the character of their contact. This work having been completed, the southern portions of the township of Burleigh and Harvey and a portion of western Cavendish were surveyed. The mapping of the entire area was thus finished. With the completion of this work it may be appropriate to state very briefly what has been accomplished.

Burleigh and Harvey.

Area covered by geological survey.

A large area in eastern Ontario, comprising about 4,200 square miles, about the geology and mineral resources of which, at the time the work was commenced, practically nothing was known, has been surveyed topographically and geologically, and a great mass of information concerning its character and resources has been collected. Two maps have been prepared. The first of these, known as map-sheet number 118 of the Ontario series, (Haliburton sheet) is on a scale of four miles to an inch, and comprises an area of 3,456 square miles, its four corners being situated respectively in the townships of Finlayson, Hagarty, Grimsthorpe and Digby and having as its chief centres of population the villages of Haliburton, Bancroft, Coe Hill, Whitney and Barry's Bay. The Ottawa, Arnprior and Parry Sound railway runs across the northern portion of the sheet, while the Victoria

Haliburton map-sheet.

branch of the Grand Trunk railway, the Irondale, Bancroft and Ottawa railway and the Central Ontario railway have their termini in the southern portion of the area.

Bancroft sheet.

The second map is a special one and is to be known as the Bancroft sheet. It comprises an area of 2,040 square miles and has been drawn on a scale of two miles to an inch. It embraces the south-eastern portion of sheet 188, reproducing it on a larger scale and it also includes the country to the south, as far as Stoney lake, representing an additional area of 680 square miles. The necessity for this second sheet arose from the impossibility of showing the geological structure of so complicated an area on so small a scale as that of sheet 188. It was also found that a study of the district to the south of the Haliburton district was necessary in order to interpret the structure of the northern area. The Bancroft sheet will represent the first large Laurentian area in Ontario which has been mapped in such detail and will show excellently the character of a typical area of the rocks of the upper division of this system. Both maps will be coloured so as to represent the areas and distribution of the several petrographical units which comprise the districts which they represent, without any attempt to modify the mapping by introducing considerations of relative age.

Granite gneiss.

The survey has shown that the northern half of the area mapped consists almost exclusively of granite-gneisses of igneous origin which would in all probability have been classed by Logan as Fundamental gneiss. The southern half of the area on the other hand, consists chiefly of a series of very ancient sedimentary rocks, largely limestones, which rests upon the gneissic series, but which has been invaded and altered by it. Large areas of the sedimentary series have been so shattered and penetrated by the granite-gneiss that a sort of breccia on an enormous scale has resulted. Great bathylites of the granitic rock arch up and break through the sedimentary series elsewhere, the latter being wrapped around the bathylites in great sweeping curves.

Bathylitic structure.

The same bathylite structure is observable in the northern gneisses also, and can be traced by the curving strikes of the foliation of the gneiss, but here the limestones have been swept away by erosion.

In the south-eastern portion of the area the limestones are found in a comparatively unaltered condition and are associated with great volumes of amphibolite and other foliated rocks, as well as with occasional bands of conglomerates—some of which, at least, have been shown by Dr. Barlow to be of autoclastic origin. The amphibolites are in part altered volcanic tufas. A great volume of nepheline syenite has been

Autoclastic rocks.

shown by the survey to occur, associated with the limestones in the southern portion of the area. This remarkable rock has apparently some genetic connection with the limestones and also with the granites. Great intrusions of gabbro have also been found associated with the amphibolites in several parts of the district, and quite apart from these latter rocks marked evidences of volcanic action have been observed in several parts of the Bancroft sheet.

Economic minerals.

The area embraced by the survey is one which contains many mineral deposits of economic value—iron ores, mica, corundum, apatite, mineral paint, etc. These have, in all cases, been examined and their description will constitute an important chapter in the report now in course of preparation, which will form a compendium of all that is known of the mineral resources of the area in question.

BOTANY AND ZOOLOGY.

Professor John Macoun.

Catalogue of plants.

Since my last report of progress was completed I have continued to conduct the correspondence and to perform the usual routine work of this Branch. When an opportunity offered last winter I worked on Part VII of the Catalogue of Canadian Plants and was able to finish it before spring. This part includes the Hepaticæ (Liverworts), Lichenes (Lichens) and an addendum to Part VI—the Musci. It is unnecessary to refer in detail to the enormous amount of work involved in the above and in the examination and labelling of a large number of specimens.

The following table will, however, give some idea of the latter:—

Liverworts	1,874
Lichens	3,892
Mosses	11,025
Total	16,791

These 16,791 specimens are now in the cases in the herbarium and are arranged in such a way that any one taking Parts VI and VII of the catalogue can see the various species and forms mentioned in the text. This work is now in the hands of the King's Printer, and the first part—the Liverworts—has been printed.

Flora of S. W. Ontario.

For many years I had desired to investigate the flora of southwestern Ontario and it was understood before the death of Dr. G.

M. Dawson that I should take up that work during the summer of 1901. It seemed advisable, from a scientific standpoint, to examine the flora and fauna of the Grand river and see how they compared with those of the south shore of Lake Erie. Both the late Dr. Dawson and yourself considered it better to take a broader field and to look more at the economic side of the question and make some sort of report on the fruit-producing capabilities of the region traversed. With the above object in view, I left Ottawa on May 8 and returned on September 7, after spending four months in the field.

Owing to the work I have had to carry on in many distant fields and the multiplication of duties, a proper examination of the flora of the interlake peninsula of Ontario had never been made. Sir William Hooker, in a letter to the writer in 1861, urged him to make a personal examination of the shore of Lake Erie and stated that less was known of the flora bordering on the great lakes than of that within the Arctic circle.

As the natural flora of a country is an index of its capabilities and climatic conditions, so an examination and enumeration of the various species of plants growing in a given region, will, when properly understood, solve the problem of the success or failure of any branch of agriculture in that region. Owing to this knowledge, the writer was enabled in 1872 and in later years, in the face of continuous opposition, to publish to the world the suitability of Manitoba and the prairie region generally for the growing of cereals. It was only from a knowledge of its plants that he could do this, and as nature never errs, his prophecies have been entirely fulfilled.

Fruit-growing.

Of late years fruit-growing has been a paying branch of agriculture, and the Niagara peninsula and Essex county have been the advertised counties for its production. It was thought that an examination of the country would show that these areas could be greatly enlarged and that fruit culture could be made profitable over the entire district. Acting on this thought, the country between the Niagara river and Owen Sound was thoroughly examined during the past summer and over 1,400 species of plants collected. In no instance was anything found to indicate a lack of warmth and everything favoured the assertion that the whole region was suitable for the cultivation of fruit, ranging from small fruits to cherries, plums, apples, pears, peaches and grapes. There can be no question regarding this matter, as wherever the growing of fruit has been attempted it has been a success if properly undertaken. The purpose of this report is not to speak of fruit-growing in any special section of the region, but to refer particularly to the natural fruit and its bearing on the products of the soil generally.

Niagara.

On May 8 work was commenced at Niagara Falls and a note made of the plants found growing within a radius of eleven miles of that point. Special attention was given to the old forest growth, which largely consisted of hickory and oak, though no less than thirty species of trees were enumerated. Later it was found that the same forest trees, with variations on account of soil, extended to Windsor. These trees differ very much from those met with on Lake Huron and east of Toronto and it may be safely said that this difference in the forest growth must result from a milder climate in winter in the south-western part of the province. Peaches are the most tender fruit grown in Canada and at present heavy crops are raised between Hamilton and Queenston, and indeed wherever attempts have been made in the Niagara peninsula. A similar fruit centre is the district around Leamington and Kingsville in the county of Essex. This district has the same forest growth that is found at Niagara and the climate is practically the same. It is perhaps needless to say that fruit culture with profit can be carried on in every part of the country between these two points.

Leamington and vicinity.

Although the peach has been just selected as an example, it was not meant to exclude other fruits. Cherries, plums, pears, apples, grapes and small fruits succeed equally well. The capacity of the country under discussion for growing crops has hitherto been little understood, as tobacco culture is only now becoming a remunerative business. Only a few years ago it was scarcely thought of as a paying crop, yet in 1900 one firm paid out over $250,000 for that raised in the neighbourhood of Leamington. A very large tobacco warehouse was being erected at Leamington last summer by another firm and it was currently reported when I was there in August that 5,000 acres of tobacco were under cultivation for it.

Tobacco.

Collections of plants were made at many points, and in every locality visited the growth was noted, and the conviction forced itself upon me that the capacity of the whole region was only limited by the amount of intelligence brought to bear upon its natural capabilities.

Lake Huron.

Less time was spent on Lake Huron than Lake Erie, but the counties bordering on the former and on Lake St. Clair are known for their grain and general fertility and locally for their fruit. The time will come when the export of apples from this large area will be second to that of no other part of Ontario. The soil in most places is of the right kind, being largely mixed with lime, and the climate being cooler than that on Lake Erie, the fruit will be later in ripening and hence will keep better.

Apple raising.

Apple-raising in the past in many districts has been a hap-hazard business. Each farmer put out an orchard, generally leaving the agent to select his stock, took more or less care of it, and waited for returns. Returns came in the shape of fall or late summer apples but scarcely any winter varieties, and hence no return in a monetary sense for the time and labour spent. This has been the case in parts of Essex county, where fine orchards have been cut down because they yielded only unsaleable fruit. Orchards planted with winter varieties in any of the counties north of the Thames must of necessity be expected to produce good fruit, and I look to this region for the future winter supply of Manitoba and the North-west until the prairie provinces produce their own fruit.

During two weeks in May large collections of botanical specimens were made in the vicinity of Niagara Falls, and on the 23rd of that month I took the train for Leamington, in Essex county. Though having my headquarters there, I made trips to Ridgetown, Kingsville, Arner, Amherstburg, Sandwich and Windsor. In all these places I secured large collections and added numerous species to our known southern flora. From a cursory inspection very little can be learned except in a general way, so I made a thorough examination of the district, and am satisfied that Lake Erie and the Detroit river and even Lake St. Clair, by no means form natural limits to the flora, either of Ontario or the States to the south. This deduction is based on the natural floras of the whole districts and from their identity. It is probable that the Canadian side is warmer in the autumn, owing to the heat from the water being blown in upon it at that season.

Southern trees.

Three trees which range as far south as Texas come to perfection both at Niagara and Leamington, and very likely in the intervening country. These are the custard apple *(Asimna triloba)*, the sassafras *(Sassafras officinale)* and the red mulberry *(Morus rubra)*. These trees, coming to perfection in the district, show that its climate is much milder in winter than would be expected from its latitude. The herbaceous plants are even more southern in their facies, and indicate a warm summer climate. This is more apparent in Essex county than it is in the vicinity of Niagara Falls.

Valley of the Thames.

Chatham and the valley of the Thames was visited and numerous rare and interesting plants were seen in perfection, and the astonishing growth of weeds and native plants gave proof of the richness of the soil. Here is seen an assemblage of plants that it was hardly expected could find a home so far north. These were cup plant *(Silphium perfoliatum)*, prairie dock (*Silphium terebinthinaceum*) and *Actinomeris squarrosa*, all of which grew in great luxuriance along the Thames.

Many other rare and beautiful plants were seen, but none equalled the rose mallow *(Hibiscus moscheutos)* and the tall orange lily *(Lilium superbum)*, which were far from rare on the line of railway towards Windsor.

Windsor and vicinity.

A visit had been made to Amherstburg, Windsor and Sandwich in June and many things noted as worthy of record. On this account the last ten days in July were spent at Sandwich and a large collection of plants made, which had many points in common with prairie species. Indeed, many species found in the woods were more at home in grassy glades which seem to have been their natural habitat. Of these species were *Liatris spicata*, *L. scariosa*, *Ludwigia alternifolia*, *L. polycarpa*, *Vernonia Macounii*, a new species, *Lycopus lucidus*, and many others. The woods were full of species that had seemingly only crossed the border, though some of these were found at Leamington also. The flora of Essex county requires careful examination, and many species will yet be found that have not hitherto been recorded as Canadian. These are rare, of course, and are of more interest to the botanist than the general public.

Pelee point.

The flora of Pelee point and Pelee island is of this character, but in the little time at my disposal, exhaustive work could not be done. On Pelee point, however, fine specimens of the blue ash *(Fraxinus quadrangulata)* and the three-thorned acacia *(Gleditschia triacanthos)* were seen, and the nettle tree *(Celtis occidentalis)* occupied more than half the area on some parts of the point. Pelee island has many interesting species; the more notable trees not found on the north shore were the red bud *(Cercis Canadensis)*, Kentucky coffee tree *(Gymnocladus Canadensis)*, and *Tilia heterophylla*, a southern form of basswood.

Some time was spent at Wallaceburg, near Lake St. Clair, and although the flora was very rich, few species not seen elsewhere were noted. The wheat fields and meadows in this section were covered with heavy crops and large areas were planted with the sugar beet, which, I was told, is one of the staples of the district.

Sarnia and vicinity.

The careful study of the country near Sarnia being necessary, I remained there for ten days in June and about the same time in August. Like Sandwich and Windsor, this district has many peculiar plants, but the most interesting thing noticed was the influx of more northern species, showing that the colder water of Lake Huron had a tendency to lower the general temperature. It would be interesting to know what the difference of the winter and summer temperature is between Windsor and Sarnia. Here the hickories and oaks had largely disappeared and the sugar maple was the principal tree. The sandy point around Point Edward at the outlet of Lake Huron and the marsh between it and Sarnia, has a flora in many respects peculiar to itself. Being either sand or marsh, its flora partakes of the nature of these, and is not, for that reason, indicative of climate. Visits were made to Camlachie and Wyoming, where the nature of the forest, away from the sand, could be more easily seen.

Goderich.

A visit to Goderich showed that the Lake Huron forest was almost identical with that of Hastings or Northumberland counties, except that elm, maple and black cherry were larger and better developed on Lake Huron than east of Toronto. Numerous herbaceous plants were seen, but very few were uncommon or of peculiar interest. In the river bed tuberous Indian plantain (*Cacalia tuberosa*) was found, and associated with it another rare species, Great St. John's wort (*Hypericum Ascyron*). The valley of the river Maitland is deep and quite narrow near its mouth, and on this account has not the flora which is usually found in such places.

Between Goderich and Southampton the forest everywhere proved that the estimate I had formed of it on the lower part of Lake Huron held good. The same terms may be applied to the lower part of the Bruce peninsula and the country between Southampton and Owen Sound. Indeed the whole district, extending almost to Collingwood, may be included in the future apple-growing area of western Ontario.

Bruce peninsula.

An examination of the Bruce peninsula showed that from the Fishing islands to Cape Hurd or Tobermory the shore facing Lake Huron was low and almost bare of soil, with shallow water for a long distance from the land. On shore, the land rose gradually and was very rocky and totally unfitted for cultivation. The coast facing the Georgian Bay was said to be quite elevated and the land, at least in part, suited for farming purposes.

From the plants found along the shore I surmise that the ice is piled there in spring and that vegetation is somewhat retarded thereby. Asters and other composites were in great profusion, and some forms were collected that may possibly be new to Ontario. Near Tobermory many new species were collected, among them *Solidago Gillmani*, new to Canada, and *Helenium Huronense*, new to science. Owing to the clearness of the water, there was no difficulty in seeing the bottom at twenty-five and even thirty feet. The lake for hours would often be perfectly smooth and while the lead was being cast we could examine the bottom by looking over the side of the boat.

During the last two months of field-work I was assisted by Mr. Percy Marshall and with his help was enabled to make much larger collections than would otherwise have been possible.

With the exception of a few reptiles and batrachians no natural history specimens besides plants were collected.

Collections received.

As usual there have been many collections of plants examined at the office besides those brought in by the members of the staff. Three collections from Prince Edward Island, sent by Mr. Lawrence Watson. A very fine collection from Labrador, sent by Dr. Alex. McKay. A large and valuable collection from Anticosti, sent by the Abbé Laflamme, of Laval University, Que. A collection of Ontario plants sent by Mr. W. Scott, head master of the Normal School, Toronto. Collections made at Banff, Rocky Mountains, were sent by Mr. N. B. Sanson, curator of the museum there. Collections were sent from British Columbia, by J. A. Pinco, B.A., head master of the High School, Victoria, by J. R. Anderson, Deputy Minister of Agriculture, Victoria, and by R. H. Jameson, who collected in many parts of the province. Mr. Gwillim, formerly a member of this staff, sent a very nice collection from Nelson, B.C., and another was received from Miss E. Girdwood, of Cottonwood, B.C. Besides these many minor collections were sent to the office and the naming of these, with the correspondence involved, took far more time than the above enumerations would convey to the reader. My own collections this year amounted to over 2,500 sheets of specimens, representing upwards of 1,600 species. The sorting and naming of these and getting them in order was no small undertaking, but this has been done since my return from the field.

I am now engaged in reading the proofs of Part VII of the Catalogue of Plants, and in preparing the MSS of Part II of the Catalogue of Canadian Birds, which I hope to have nearly completed by next spring.

Future work.

The writing of Part VIII of the Catalogue of Canadian Plants is in contemplation; this will conclude my work on Botany. When written it will include the characeæ, sea-weeds and at least 1,000 specimens of fungi. Before completing this work, however, it will be necessary to have a better knowledge of the sea-weeds of the St. Lawrence river and gulf. Large collections have already been made of the Pacific coast species, and consequently our knowledge of them is much more complete than of those nearer home.

Presentations.

Presentations.—Mr. C. Scrim presented to the museum a section of two trees, *Pinus strobus* and *Quercus rubra*, which had grown together in the form of an X; the specimen is about three feet high and the two trees were fastened together by the bark.

A very fine specimen of *Polyporus fomentarius* was presented by Mr. Leggatt, of the *Evening Journal.*

A specimen of wood showing an extraordinary example of the filling up and repair of tissue was sent to the museum by M. L. W. Shipman, of Almonte, Ontario.

Herbarium work.

My assistant, Mr. J. M. Macoun, did not return from the Paris Exhibition until January, and on that account the number of specimens mounted and distributed during the year was not as large as it would otherwise have been. Since my last summary report was written 4,195 sheets of specimens have been mounted and placed in the herbarium cases. Of these 2,150 were Canadian, 576 from the United States and 579 from Europe and other foreign countries; 910 sheets of Cryptogams were also mounted; 1,660 sheets of specimens were distributed from the herbarium, chiefly in exchange for specimens received. The principal institutions to which specimens were sent are:

New York Botanical Gardens.............	257
U. S. National Museum.......	263
Kew Gardens	220
Natal Botanical Gardens..................	150

We are still very deeply in debt for specimens received from individuals and public institutions, but hope during the coming winter to find time to label and distribute a sufficient number of specimens to more than balance all our accounts.

Several large contributions have been made to our herbarium from foreign countries during the past year. These include collections from Alaska, sent by the N.Y. Botanical Gardens, from the Western United States, sent by the U.S. National Museum, and about 1,100 specimens from the Missouri Botanic Gardens. These last are a part of Dr. Engelmann's private collection.

Work of assistants.

The employment of Miss Stewart as our clerical assistant will enable us to bring the general work of the branch more nearly up to date this winter than it has been before. Since her employment she has been chiefly engaged in filing arrears of letters, writing labels and in completing the numbering of the sheets of botanical specimens in our herbarium. Since January 1, Miss Stewart has for two hours each day assisted the librarian. Several years ago, we adopted the system of placing a running number on every sheet of specimens mounted, and Miss Stewart has just completed the numbering of the Canadian specimens mounted before this system was adopted. Of Canadian flowering plants alone we have now 32,431 mounted sheets.

Assistant botanist.

After his return from Paris, my assistant (Mr. J. M. Macoun) was chiefly occupied until spring with accumulated arrears of office work, which included the determinations of specimens left over from previous years. During May he spent some time in a further study of the violets of the region about Ottawa, several new species being added to those already known. Descriptions of these and other new species have been published from time to time in *The Ottawa Naturalist* and elsewhere, and I would respectfully draw your attention to the need of some publication in the form of an annual bulletin, in which we could record the progress made in Natural History work in Canada.

NATURAL HISTORY OF THE INTERNATIONAL BOUNDARY.

Mr. J. M. Macoun having been appointed naturalist to the Canadian International Boundary Commission, joined Mr. J. J. McArthur's party at Chilliwack, B.C., on June 11, and worked in the Chilliwack valley until September 3. He makes the following report:

Boundary Commission.

'As soon as I was notified of my appointment as naturalist to the Boundary Commission, I took steps to secure the services of Mr. William Spreadborough of Bracebridge, Ont., who has been attached to one or other of the Geological Survey parties as field naturalist during every season but one since 1888. Mr. Spreadborough went at once to Chilliwack and had been collecting birds, mammals and plants in that vicinity for about three weeks when I reached there on the afternoon of June 11. My instructions were to join Mr. McArthur as soon as possible. Mr. McArthur happening to visit Chilliwack that evening, I delayed my departure until the next day, when I accompanied him to his camp about twelve miles from the village.

Cutting trail.

'Having learned from Mr. McArthur that his progress up the Chilliwack river was very slow on account of the difficulty he was experiencing in cutting a trail through the dense forest, I decided that I would remain on the outskirts of the forest until he had reached Chilliwack lake. This arrangement permitted me to make a very thorough study of the flora and fauna of the valley in the immediate vicinity of the Chilliwack river, and of the low hills which bordered it in the vicinity of our camp. At this time, and during the whole season, Mr. Spreadborough was occupied in collecting and preserving the skins of birds and small mammals.

'After remaining two weeks at "Macguire's" where my first camp was established, I moved about ten miles up the river to "Thurston's" where there was a small clearing. After collecting there for a few days I started for Chilliwack lake on July 5, Mr. McArthur furnishing me with the means of transport. From July 6 until July 31 I worked in the vicinity of Chilliwack lake, ascending most of the mountains which border it. In nearly all of these ascents I was accompanied by Mr. Spreadborough and when necessary we camped for one or more nights near the summit of the mountain we happened to be on. During the period I was on Chilliwack lake I made Mr. McArthur's camp my headquarters, and was furnished by him with supplies and transport whenever I required them.

Chilliwack lake.

'Between July 31 and August 19 I worked slowly down the Chilliwack river, ascending mountains to the north and south of the river. Three days were spent on the Cheam range and, with the exception of this trip, my whole work, up to this date was done either on the International Boundary or within a few miles of it. Even when on the Cheam range the boundary was only about ten miles distant.

'On August 20, I went to Sumas lake in order to study the flora of the so-called Sumass "prairie". I remained there three days and made a complete collection of the plants in the vicinity of the lake, while Mr. Spreadborough collected birds, mammals and reptiles.

'Rejoining Mr. McArthur's camp at the mouth of Tami Hy creek, Mr. Spreadborough and I ascended the mountain of the same name on August 28, camping near the summit for three days. This finished my botanical work for the season and I started for Ottawa on September 3, leaving Mr. Spreadborough to collect birds and small mammals. He continued at work until November. The result of the season's work in specimens was 1,972 sheets of botanical specimens, 442 skins of birds and mammals, about 300 reptiles and batrachians, and a few shells and insects.

Specimens collected.

'Since my return from the field my time has been in part occupied in studying the specimens collected during the summer. In nearly every large genus of plants new species were discovered and many species hitherto unknown in Canada were collected. It will require the whole winter to work the specimens up properly, and no detailed report on either the plants or animals of the Chilliwack valley can be written until this is done. The specimens collected in British Columbia in previous years are being studied with those collected in 1901, and my complete report, when published, will include the work done by others in earlier years.

New species.

'The arrangement by which I was made dependent upon Mr. McArthur for supplies and transport worked satisfactorily in every respect and Mr. McArthur not only was at all times willing to assist me in my work, but his long experience in mountain surveying and exploration enabled him to make many suggestions to me that greatly increased the results of my work.'

ON BORINGS FOR NATURAL GAS, PETROLEUM AND WATER; ALSO NOTES ON THE SURFACE GEOLOGY OF PART OF ONTARIO.

Dr. Robert Chalmers.

Wells and borings.

Your instructions to me in May last regarding field-work for the season were to undertake an investigation of the wells and borings for petroleum, natural gas, brines and potable waters in that part of the province of Ontario extending from the St. Lawrence river westward to Lake Erie and Lake Huron, and also to study the surface geology at all localities which might be visited. Considerable progress has been made in this work, but owing to the extent of the field and the varied character of the investigations, it could not be carried out in sufficient detail in the time allotted to enable me fully to report upon it. This is more particularly the case in regard to the inquiry concerning natural gas and oil, and the water supply of cities and towns. Although it was found difficult to get exact data on these subjects, still a large amount of valuable information has been secured. A great deal of exploratory work in search of gas and petroleum is now going on, the results of which are not yet available. Moreover, some of the smaller gas and oil fields recently exploited seem likely to be extended, and it would be premature at present to make any statements regarding their prospective value. All that can be done in this report, therefore, is to record as briefly as possible the facts which came under my notice, making special mention of matters of economic importance.*

Valuable information secured.

Economic importance.

Brockville.

I left Ottawa on the 21st of May and commenced work at Prescott. Dr. Ells of this Survey joined me at Brockville, and a few days were spent by us between that place and Kingston, endeavouring to ascertain the relation between the marine Pleistocene deposits in the upper part of the St. Lawrence valley and the clays and sands of the Lake Ontario basin. The western limit of the marine beds was found at Brockville and northward along the line of the Canadian Pacific railway to Smith's Falls, while Erie clay, supposed to be of fresh water formation, was noted at Lyn, Gananoque, Kingston and west-

Limit of marine beds.

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*See Report on Natural Gas and Petroleum in Ontario prior to 1891. By H. P. H. Brumell, part Q, Annual Report, Geol. Surv. Can., vol. V, 1890-91.

ward. Proceeding from Kingston to the natural gas and petroleum fields of the Ontario peninsula, I was engaged almost uninterruptedly in that region till the close of field-work on the 12th of October.

THE OIL FIELDS OF LAMBTON COUNTY.

Lambton county.

The oil wells of Petrolea, Oil Springs and Sarnia naturally demanded the first attention from their importance. In this investigation I was greatly assisted by Mr. James Kerr, of Petrolea, who has made a special study of the oil wells of Ontario since they were first operated. A number of these wells have been yielding oil since 1860-61, and, as might be expected, there has been a greater or less falling off in the quantity produced, a certain proportion of the wells giving out from time to time. A large number of new wells have, however, been put down every year, so that the supply of oil has been kept up nearly to the average. The usual depth of the oil-bearing formation is from 450 to 475 feet. As the surface deposits are from 100 to 125 feet thick, the rock has to be penetrated only about 350 feet.* Well drilling is, therefore, not a very expensive business, and in some parts of the Petrolea field the ground is literally riddled with wells, which are often not more than 200 to 300 feet apart. At present there are few of these that yield more than a barrel of oil a day, while most of them furnish much less. One operator informed me that he had 120 wells in a certain part of the Petrolea field which gave him about 100 barrels of oil a week. This may perhaps be taken as the average yield. The total number of wells now producing oil in the county of Lambton is approximately estimated at from 10,000 to 11,000. They all terminate in the Corniferous formation. The greater part of the petroleum obtained from the wells of Lambton county is sold to the Imperial Oil Company, whose refinery is at Sarnia.

Yielding oil since 1860.

Thickness of strata.

Average yield.

Test well.

A deep test well was drilled at Petrolea in 1900, terminating some 432 feet in the Trenton. The total depth of the well was 3,777 feet. The Onondaga salt group was struck at 1,275 feet and was found to be 895 feet thick. The water in the well was shut off by a 6¼ inch casing. No oil, gas or salt water was found.

Bothwell Oil Field.

Bothwell.

A new local oil field has been opened up near Bothwell in the township of Zone, Kent county, a short distance to the south-west of the former oil field of the Thames valley in the township of Mosa, which was known as the Bothwell field and wrought for some years. This new oil pool lies between the Grand Trunk railway and the Thames river, about two miles and a half west of the village of Bothwell. Mr. J. F. Carman was the discoverer. He and Dr. Fairbanks, Messrs. Brewer and Puddicombe, together with Hiram Walker & Sons are the principal operators. Messrs. Clark and Elliot have oil wells to the east of Bothwell village. The oil is found in a limestone at about 400 feet beneath the surface, or rather from 395 to 410 feet. The beds passed through in drilling consist of (1) 210 to 212 feet of surface materials, (2) a few inches of dark shale, probably Hamilton, and (3) 175 to 200 feet of Corniferous limestone. Each of the operators mentioned has a separate oil area and power-house. The total number of producing wells at the time of my visit was from 200 to 240, but new ones are continually being sunk. The yield of oil is from ten to fifty barrels a month for each well, and a total of 5,000 to 6,000 barrels a month for the whole oil field.

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* "The Ontario Oil Field" was described by Dr. Robert Bell in a paper read before the Royal Society of Canada in May, 1887.

Beds passed through.

Output.

The oil belt is five or six miles long, following the Thames river, and from a half to three-quarters of a mile wide; but a smaller oil pool has lately been opened up to the north of this, on what is supposed to be a separate anticlinal. In this oil field, there are said to be three or more north-east and south-west anticlinal axes—one main axis and several subordinate ones. Another series of anticlinals crosses these at a wide angle. The productive oil wells are found at the intersection of the two sets. The dip is lower on the southern sides of these anticlinals than on the northern, and consequently oil occurs further from the axes on the former side.

Anticlinals.

Dutton Oil Field.

Dutton.

Another oil pool has recently been opened up at Dutton, in the township of Dunwich, Elgin county, about three-quarters of a mile from the Lake Erie shore. The wells here, thirty-two in number, yield from 1,000 to 1,100 barrels a month. They are about 435 feet deep, 255 feet of this being surface beds. The rock consists of 165 feet of limestone, probably Corniferous, with sandstone beneath. The oil is said to be in the sandstone.

Tilsonburg Oil Wells.

Tilsonburg.

Wells from which oil was obtained were sunk in Dereham township near Tilsonburg in 1861. Recently several other wells were drilled in the vicinity of this town, but they failed to give oil in quantity. Last year, however, Mr. J. W. Cuthbertson, of Tilsonburg, sank two wells in the valley of Big Otter creek, below the town and has met with success.

The upper well (No. 1) is just above the Grand Trunk railway bridge (Wabash line) on lot 6, concession XII of Dereham in Oxford county. The boring is 268 feet deep and passes through (1) surface beds 81 feet, (2) rock 187 feet, the latter consisting of limestone (Corniferous) and sandstone beneath, as at Dutton. The flow of oil from this well is about 24 barrels a day.

Three new wells.

No. 2 well is about a mile and a half below No. 1, in the valley of Otter creek. In it the beds passed through consist of 74 feet of surface materials, with limestone and sandstone beneath, as in No. 1 well. The oil comes from the sandstone, which is probably of the Oriskany formation. This well (No. 2) yielded at first about seven barrels in the 24 hours, but the flow fell off to about a barrel and a half at the time of my visit.

A new well (No. 3) was being drilled when I was there (October 7), about midway between the two others. A depth of 165 feet had been reached and the limestone at that horizon had a perceptible odour of petroleum.

The facts in regard to these smaller oil pools show that the districts in which they occur were not thoroughly explored in former years, and that not only the Corniferous limestones but the underlying sandstone is oil-bearing.

NATURAL GAS.

Natural gas.

The principal gas fields of Ontario, as is well known, are situated in Essex and Welland counties. The Essex field, first opened up in 1891, has been the most productive. It is, however, of very limited extent, being only about five miles long, following the Lake Erie shore from Kingsville to Leamington, and about one mile wide. To show how this small field has been drawn upon, it may be stated that there was exported from it to Detroit alone between February, 1895, and July, 1901, 9,639,355,600 cubic feet of gas. These are probably minimum figures and besides there was a considerable export to Toledo, not to mention the quantities supplied to the Canadian towns and villages. This heavy drain on the gas storage of such a small area could naturally have but one result, namely, speedy exhaustion, and for the last year or two the supply has declined so rapidly that consumers fear they may very soon be left without any gas at all. In the hope of maintaining the supply, the United Gas Company undertook, during the past summer, to clean out and deepen the existing wells and to sink others to a considerable depth in the gas field in order to test the productiveness or otherwise of the Trenton formation. The salt water

Kingsville.

Exhaustion.

Deep wells.

was pumped out of the wells and it was found that this operation was followed by an increase in the gas pressure, but it was only temporary, for soon after pumping ceased, the wells went back to their former condition. In the deep wells no gas was found, though the Trenton seems to have been reached at several points. Since my return from the field, however, I have heard that a new supply has been obtained from a well sunk at Wheatley, but particulars are wanting.

Gas from oil wells.

Several of the oil wells in Sarnia and Plympton townships, Lambton county, yield gas in small quantities, sufficient to heat and light the farm houses in the vicinity and furnish the power necessary to drive the pumps of the oil wells. The gas from these has been used for many years.

Gas in the Thames Valley.

Thames valley.

Natural gas is found in the surface deposits on the south side of the Thames in the townships of Orford and Aldborough, at a depth of 90 feet. A hard-pan occurs here, beneath which there is a bed of sand and gravel. It is in this that the gas is found. The farmers bore for it and pipe it to their houses, using it for heating and lighting purposes.

The Welland Gas Field.

Welland gas field.

This is the largest known gas area of the province, being eight or ten miles long and from two to four miles wide, and has been operated since 1890. The principal portion of the gas is piped to Fort Erie and Buffalo, N.Y. The wells are from 750 to 850 feet deep. In the shallower wells to the west of the Welland canal the gas is said to come from the Clinton, and in the deeper wells to the east and south-east from the Medina, although these formations may not be its original source. Mr. D. A. Coste, manager of the Provincial Gas Co., informs me that very little falling off is noticed in the supply of gas in the Welland field. The company employs men who look carefully after the wells, keeping them clean and pumping out at once any water which may get into them.

Source of the gas.

Deep wells.

Deep wells have recently been sunk in the Welland field—one on lot 4, concession V, township of Willoughby, (No. 143) to the depth of 3,032 feet. Drilling stopped at what was supposed to be the Calciferous formation. Salt water was struck at 3,030 feet. There was little showing of gas, and this only in the bottom sandrock. The Clinton formation was reached at 473 feet from the surface and the Medina at 594 feet; the base of the Medina at 614 and the summit of the Trenton at 2,313 feet. From the base of the Medina to the summit of the Trenton the rocks seemed to be all shales,

Another deep well was drilled on lot 9, concession II of Humberstone, seven miles south-west of the last. The granite was struck at 3,300 feet. Neither gas nor oil was found.

The Dunnville Gas Area.

Dunnville gas area.

In Haldimand county, four or five miles north-east of the town of Dunnville, gas has been found in paying quantity. The gas wells are situated in Moulton township, near Diltz station on the Michigan Central railway. One of these, when sunk a few years ago, yielded 1,000,000 cubic feet a day. Other wells producing gas in less quantities have been drilled in this area. The town of Dunnville is supplied with gas from wells in this vicinity. Drilling was going on at the time of my visit, and it is supposed the gas field extends further to the north-east towards the county line. The depth of the wells and the thickness of the formations yielding the gas are the same as in the Welland field west of the canal. The surface deposits are about 100 feet thick. About twenty-one wells have already been drilled. Salt water is reached at 300 to 400 feet.

Gas in Pelee Island.

Gas in Pelee island.

Gas and petroleum were found many years ago on Pelee island, in the geological horizon at which they occur in Essex county, but in quite limited quantities. Since that time, further development work has been attempted but without satisfactory results. The wells are situated in the central part of the island and were sunk to a depth of about 800 feet. Only two derricks were standing at the time of my visit, and the pump at one of these was idle. A small flow of gas was escaping with the oil from the other well. This is piped and utilized in heating a couple of farm houses in the vicinity. These wells were put down near an anticline in the highest part of the island.

The Hepworth Gas Wells.

Hepworth gas wells.

Borings for natural gas and oil were carried on at different places in the counties of Grey and Bruce for some years, but without success. Last year, however, a company called The Grey and Bruce Oil and Gas Company, Limited, was formed and commenced operations in the vicinity of the village of Hepworth. Two wells, starting in the iagara formation; were sunk into the Trenton limestone. The first

Depth of wells.

(No. 1) was put down to a depth of 1,420 feet and is reported to have yielded 250,000 cubic feet of gas per day. This well gave salt water at 760 feet from the surface. No. 2 well was drilled to a depth of 1,409 feet, going into the Trenton formation 359 feet where gas was found in quantity. The pressure at first was 400 lbs. to the square inch and the flow 500,000 cubic feet a day. The company has recently installed a gas plant and is supplying the village of Hepworth with gas for illuminating and heating purposes. A third well was being sunk which the company hoped to finish this winter. These wells are on lot 1, concession X, township of Amabel, county of Bruce, and near Hepworth station, Grand Trunk railway.

SALT WELLS.

Salt wells.

No changes have of late years taken place in the salt industry of Ontario, further than the sinking of a number of wells at Windsor and the erection of a salt block there by the Windsor Salt Company. This company is now manufacturing 800 barrels of salt a day and practically controls the salt business of Ontario. Salt is manufactured at Sarnia, Clinton, Wingham and Kincardine, but on a smaller scale, as the market is limited.

Extent of salt beds.

The salt-bearing formation of Ontario seems to be of great extent and it contains a number of separate beds of this mineral one above another. Commencing at Kincardine on the Lake Huron shore, they are found to extend southward in a wide irregular belt of country to the St. Clair river, thence across the whole breadth of the south-western part of the Ontario peninsula to Lake Erie, and they apparently occupy a basin extending north-eastward up the Thames valley. The quantity of salt in the area referred to is practically unlimited, and forms an asset among the undeveloped resources of the province which must have a great future value.

WATER SUPPLY.

Water supply.

Although the rainfall in Ontario is amply sufficient to afford a good supply of water everywhere throughout the country, even in those places farthest from lakes and rivers, yet good water for domestic purposes is often difficult to obtain from wells in the solid rock. In districts underlaid by salt beds the water from such wells is usually saline or brackish, the brines permeating the shales and sandstone and sometimes even the limestones. Even where no beds of common salt exist, the waters from the deeper strata are frequently impure owing to the presence of other ingredients in solution, which sometimes render them unfit for domestic use. Sulphurous waters from such sources are also common. On account of these impurities, some of the towns obtain their water supply from that stored in the thick beds of sand and gravel on the higher grounds and in the banks of rivers and brooks. Where these beds rest on compact Erie clay or upon the boulder-clays, as they sometimes do, the water stored in the former escapes along the line o contact of the loose deposits with the underlying clay. A series of springs may thus occur at or near the foot of a bank where the water may be collected into basins and constitute a considerable water supply. In ordinary seasons, a sufficient quantity may always be obtained in this way, but in seasons of drought or when a destructive fire takes place, a community depending upon such a supply may be awakened to the fact that it is inadequate or at least is not to be depended upon in an emergency, and they seek for means of supplementing that obtained from such sources. This has been accomplished by boring artesian wells in a few cases, but the problem of supplying water to some of the towns in southern Ontario has not yet been satisfactorily solved.

Saline and sulphurous waters.

Cause of springs.

A few towns obtain their water from rivers and filter it through gravel and sand or purify it by other means. But in the thickly settled parts of the country the stream waters have become more or less contaminated from the refuse of the towns and villages along their banks and thus become generally unfit for use. The system of purifying these waters, otherwise than by the filtration process mentioned, will require to be adopted to render them serviceable or potable. A number of towns pipe their water supply from the nearest lake. Petrolea, for example, has a main laid from Lake Huron.

Water supply from rivers and lakes.

PLEISTOCENE GEOLOGY.

The Pleistocene geology of the part of Ontario under discussion is of unusual interest. The beds are of great thickness and variety, compared with those of other parts of Canada which I have visited, and their origin and history appear to be very closely connected with those of the Great Lakes, over a large part of the region. The Erie and Saugeen clays, and the Artemisia gravels of this region were described by Dr. Bell in the chapter on superficial deposits in the Geology of Canada, 1863, and my observations tended to confirm the accuracy of the descriptions there given. The immense banks of these clays observed often elicited the inquiry in my mind as to where such quantities of materials came from and by what agencies they were brought into their present positions. In many places the beds are from 100 to 250

Pleistocene geology.

Recent formations.

Thickness of beds.

feet in thickness. The surface deposits when examined and studied in detail are found to consist of a series of clays, sands and gravel, which must have been laid down under a variety of conditions. We have here land deposits as well as shallow and deep water beds. A generalized section of the whole series as observed in the Ontario peninsula exhibits formations which may be classified in the following descending order :—

Descending sequence of formations.

1. Clay and sand with gravel near the summit. The whole more or less oxidized and of a yellowish colour. The clay burns to red bricks. This clay often contains calcareous concretions and is met with throughout the whole region from the marine plain at Cornwall and Brockville westward to the higher grounds of the Ontario peninsula. At Prescott and Brockville it contains marine shells, chiefly *Macoma Balthica*, but in the west no fossils have been found in it.

2. Boulder-clay, often thick, but much denuded, underlaid by sand and silt deposits. In consequence of the denudation it occurs mostly in detached areas.

3. Arenaceous and silty beds, in places apparently forming upper parts of the Saugeen clay (No. 4).

4. Gray, partially oxidized or brownish clay, thinly stratified, becoming sandy in the upper parts. Fresh water shells occur in the lower part or at the contact with the Erie clay (No. 5). This is the Saugeen clay described in the Geology of Canada, 1863.

5. Stratified bluish-gray clay, sometimes dark in the bottom. It becomes lighter in colour when dry and burns into white bricks. This is the Erie clay described in the Geology of Canada, 1863. In the upper part, it contains fresh water and land shells such as *Campeloma* (sp.,) *Succinea obliqua*, *Polygyra thyroides*, etc.

6. Boulder clay, usually in a thin sheet.

7. Decomposed rock *in situ*, often absent.

8. The surface of the fundamental rock.

Interglacial beds.

The interglacial beds of the foregoing section are often from 100 to 150 feet thick, and it is evident that during their deposition there must have been land-surfaces in some part of the lacustrine area. The land shells were found not only in the deposits along the Lake Erie shore, but in the clays of Pelee Island ; at the latter place, from five to fifteen feet above the level of the lake. The interglacial period appears to have been of long duration.

Glacial striæ.

Glacial striæ were found at the Queenston quarries on the Niagara escarpment, with a direction of S. 48° W. On Pelee island their course is S. 80° W. These groovings were produced, it seems to me, during the second glacial period.

CHANGES IN THE LEVELS OF THE GREAT LAKES.

Levels of the Great Lakes.

It is evident to any one who examines the terraces and plains bordering the Great Lakes, that Huron and Erie and probably Ontario also, stood at higher levels at the close of the Pleistocene period than they do at the present time. In the subsidence of the waters which followed, the various lakes seem, however, to have reached a level considerably lower than that which they have now. This low-level stage probably occurred in the Recent Period, that is, since the latest of the Pleistocene beds were laid down. I may here give a few of the principal facts showing that this shrinkage of Lakes Huron, Erie and Ontario actually took place as stated. Not having visited Lake Superior I cannot speak of it from personal knowledge.*

Stumps below lake level.

1. West of Port Rowan, along the Lake Erie shore, a number of stumps of large trees, probably a score, more or less, were observed, their roots in soil below the lake level while the upper parts (of the stumps) are broken off as if by the lake ice. They are now nearly covered with sand.

Trunks o trees.

2. At Goderich the prostrate trunks of trees are found in the mouth of the Maitland river, ten to fifteen feet below the level of Lake Huron, embedded in the bottom of a layer of clay and marl. It is evident these trunks were laid down when the lake was lower. They were pointed out to me by Mr. Peter McEwen, who was one of the first to call my attention to certain facts connected with the fluctuations of the levels of the Great Lakes.

Flooded estuaries.

3. The streams discharging into Lakes Huron, St. Clair, Erie and Ontario, as, for example, the Aux Sables, Sydenham, Thames and Grand rivers, and in the Lake Ontario basin, the Humber, Don and the smaller streams to the east, including the Cataraqui at Kingston, have the lower parts of their courses flooded from the lakes. In the case of the Thames and the Sydenham, this condition extends up-stream for many miles, the depth being from ten to twenty-five or thirty feet. With existing levels, it is evident these rivers could not have eroded their channels to these depths. The lakes must, therefore, have been

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*See paper on 'The Geological History of Lake Superior,' by Dr. Robert Bell, F.R.S. (Read before the Canadian Institute, Toronto, April 15, 1899.)

at least twenty-five or thirty feet lower at one time, to have allowed the rivers to erode such channels. As a filling-up process seems to have been going on since the period of low water, the river channels were probably considerably deeper then than they are at the present time.

SAND DUNES AND SPITS.

Sand dunes and spits.

The spits and dunes along the north shore of Lake Erie seem to have been formed by materials drifted from the west. The point east of the mouth of the Detroit river, the south-west point of Pelee Island, Pelee Point, Rondeau Point, Long Point, Long Island, etc., have all been formed in this way. The movement of the sand takes place along the littoral and to a depth of fifteen or twenty feet in the lake, and is no doubt due to currents caused by the prevailing winds. It affects the mouths of harbours and necessitates the construction of piers and breakwaters, and in some places dredging is required from time to time.

Sand drift.

In the Lake Ontario basin, the sand driftage has apparently been from east to west. Toronto island and Burlington Beach may have been formed by this movement. These beach formations exemplify the conditions which prevailed in the interglacial period in this region when land and fresh water shells were buried together in the clay and sand beds of that time.

WATER SUPPLY OF LONDON, ONTARIO.

Consulted as to water supply of London

On the 11th of November I received instructions to proceed to London, Ont., to confer with the Water Commissioners of that city respecting its water supply. Two or three days were spent in company with Mr. John M. Moore, C.E., the superintendent and engineer, in examining the sites of the different wells and springs in the vicinity and collecting all the information available concerning them. Although there is no immediate danger of a shortage of water in this city, yet in view of its growth, both in regard to population and business, it was considered advisable by the commissioners to obtain the best advice possible about providing for an increased supply in the future.

Source of present supply.

The water supply of London is obtained from a number of springs on the banks of the river Thames, two to three miles below the city, at a place called Springbank. The surface formations there are gravel and sand, 200 to 300 feet thick, underlaid by a clay hardpan. These gravels and sands serve as a storehouse for the rainfall, a large part of which, after seeping through them, escapes into the river valley in the form of springs along their contact with the underlying clay. This spring water is collected into large basins or ponds which are connected with a pumphouse, and are thence forced into a reservoir 276 feet above the water works datum and from this the city main receives its pressure.

Wells in solid rock.

In our investigations, it was found that the wells sunk into the solid rock here do not yield potable waters. Wells of this kind have been drilled at the water works pumphouse, at the junction of the north and south branches of the Thames, at Carling's Brewery, and at the Insane Asylum. In the first three the waters were sulphurous; in the asylum well (2,250 feet deep) the borehole had to be closed at the bottom of the surface deposits, and the supply of water obtained by that institution is now derived from these deposits, occasionally supplemented from a pond near by. Although the Water Commissioners of London were anxious to have one or more deep artesian wells bored near the city, yet in view of the above mentioned facts, I did not feel warranted in advising them to sink any. Instead of this, the scheme of obtaining a supply of water from the river Thames was urged upon them, but though quite practicable, they contended that it involved the erection of an entirely new system of waterworks, besides the employment of filtering and purifying processes, all of which the city could not afford at present The only other sources from which water was obtainable in quantities sufficient to supplement the present supply, were new springs and wells in the surface deposits. On the North Branch, about four miles above the city, there are springs which have been computed to yield 850,000 gallons a day. The water from these could be pumped into the street main now in use. A further addition might be obtained by sinking wells in the surface deposits near the junction of the North and South Branches, also in a flat in the valley of the latter, below the Port Stanley railway bridge. At both of these points I recommended test wells to be put down to ascertain the quantity and quality of the waters, both in the recent surface beds and the underlying solid rocks.

Doubtful use of artesian wells.

Thames water might be used.

Copious springs.

Acknowledgements.

I desire in closing to express my sincere thanks to Messrs. James Kerr, of Petrolea; Peter McEwen, of Goderich; John Corrie, of Stratford; Jno. M. Moore, C.E., of London; E. P. Rowe, of Hepworth; J. S. McLister, of Bothwell; J. W. Cuthbertson, of Tilsonburg; D. A. Coste, of Buffalo, N.Y., and others for information and various acts of kindness.

THE DISTRICT AROUND KINGSTON, ONTARIO.

Dr. R. W. Ells.

Work by Dr. R. W. Ells.

The winter of 1900-01 was spent in plotting the work of the preceding year and in revising the surveys made by the late Mr. N. J. Giroux during the years 1895 and 1896, the greater part of which was put into shape for the final compilation. The area included in these surveys by Mr. Giroux extends from the Ottawa river to the River St. Lawrence, east of a line from Ottawa to Prescott.

Two reports were also written, viz., that on the map of Ottawa city and vicinity, and a revision of the report on the area included in map-sheet No. 121 of the Ontario and Quebec series, comprising the area along the lower Ottawa and extending north from that river for about fifty miles.

Field work for 1901.

Field-work for 1901 began on May 24, when, in company with Mr. R. Chalmers, nearly two weeks were spent in examining the clays and other surface deposits between Prescott and Kingston in order to search for marine shells in that district. In this connection it may be stated that these shells were found as far west as Brockville, where they occur quite plentifully in two brickyards in rear of the town, and also at an old brickyard on the road to Tin Cap, about four miles north-west of the former place. West of this, though the clays present many features similar to those seen at Prescott and Brockville, no marine organisms have yet been observed.

Surveys made along Rideau lakes.

On June 6th, work was commenced with two assistants, Mr. R. Hugh Ells, B.A., and Mr. W. L. Lodge, M.A., in the area adjacent to the Rideau canal between Oliver's Ferry and Kingston. A careful examination was made of the numerous lakes along the entire route, and a number of mica and iron deposits were examined at several points in order to compare the conditions there existing in connection with these minerals, with those found in the area north of the Ottawa river.

Route from Jones Falls to Gananoque.

From Jones Falls a route was followed, by way of the village of Morton, the Beverly lakes and the Gananoque river, to the town of Gananoque, on the St. Lawrence, and a number of road surveys were made in the country adjacent in order to fix the boundaries of the sandstone outliers in this direction. Returning to the canal at Seeley's bay, the country to the west, including the townships of

Storrington, Loughborough and Bedford was carefully studied and the area north to the Devil's lake was examined, the canal being again reached at Mud lake, near Newboro'. This district is an important one, owing to the presence of numerous deposits of mica and iron at a number of points.

Kingston and vicinity.

Returning to the St. Lawrence again, surveys were made of the roads in the townships of Pittsburgh and Kingston, in the former of which a number of scattered outliers of the Palæozoic rocks are seen. An examination was also made of the shores and islands in the river between Kingston and Gananoque, at which place the examinations of last year ended. The contacts of the overlying Cambro-Silurian limestones and sandstones with the crystalline rocks are numerous and show some interesting features. The waters of Lake Ontario were found to be too rough for small canoes, and the work was carried on by land for the remainder of the season, using a buckboard, with odometer attachment for registering the distances. In this way, over 1,000 miles of roads were surveyed, principally in the counties of Frontenac and Addington. This work was in charge of my assistant, Mr. Hugh Ells, by whom the surveys in the area north of Lake Ontario were connected with the Canadian Pacific railway and with those made further north in 1896. My other assistant, Mr. Lodge, was transferred, early in July, to another Geological Survey party.

Prince Edward county.

An examination was made of Amherst island and of several other islands in the vicinity, as also of a large part of the peninsula of Prince Edward county and the country along the Bay of Quinte as far west as the town of Trenton, which is just west of map-sheet No. 112, to which the season's work was mostly confined. In part of this work I was accompanied by Dr. H. M. Ami, who made a study of the fossils of the Black River and Trenton formations and obtained large collections from a number of localities.

After Dr. Ami's return to Ottawa, several weeks were devoted to an examination of some of the principal mining locations, especially with reference to the mica deposits, some of the mines of this mineral being among the most important yet found in Canada.

I returned to Ottawa towards the end of August and was there detained for several weeks in correcting proofs of the two reports on the geology of the areas along the Ottawa river, but the work in the Kingston district was carried on by my assistants till September 20th, the surveys westward being connected with the Canadian Pacific railway at Tweed station. Subsequently several short excursions were made in the vicinity of Ottawa to complete details of structure in connection with the map of this area.

Work of Mr. Alexander Murray.

The previous work of the Geological Survey in the Kingston and Belleville district was done by Mr. Alexander Murray, in 1852. The results were published in the Annual Report for 1852-53, now out of print, and a large amount of interesting and valuable information, is there given relative to the distribution of the sedimentary formations which are for the most part of Black River and Trenton age, underlain in places by sandstones, which at that time were supposed to belong to the Potsdam formation. Certain shales and arkose layers, resting upon the crystalline rocks at different points, with overlying beds of cherty limestones, were supposed to pertain to the horizon of the Chazy. The characters of the several divisions of the crystalline rocks which underlie these formations are well described by Mr. Murray in the report referred to.

Limestones of the Kingston district.

Among the important points to be determined in connection with the geology of the Kingston district is the age of the limestones which have a wide development about Kingston city, and throughout the area to the north and west, and their proper stratigraphical relations to certain sandstone deposits which underlie these at a number of localities. In places the limestones, which become interstratified with greenish-gray marly shales in their lower portion, rest directly upon the underlying reddish granite or other crystalline rocks; but at many points there is an intervening deposit of greenish, sandy and calcareous shales and grit, generally quite thin and rarely more than a few feet in thickness. When these beds rest directly upon the crystalline rocks they often contain small pebbles of granite and quartz and are made up of the decomposed materials of the underlying rocks, with the aspect of a true arkose. They apparently form the lowest member of the limestone formation and sometimes hold fossils, chiefly small orthoceratites and a species of *Leperditia*.

Arkose beds at base.

The contact of the limestones with the granite is well seen near the summit of the ridge in Barriefield, opposite the city of Kingston, where the calcareous strata are sometimes tilted in every direction at angles varying from ten to twenty degrees, the inclination being apparently due to conditions of deposition on a rounded underlying surface. On the shore of Deadman's cove to the east of Barriefield hill, there is a thin underlying deposit of the green arkose filling the irregularities in the granite surface and passing directly upward into the limestone.

Road between Gananoque and Kingston.

The shore road from Gananoque to Kingston shows these limestones at several points. That they are of Black River age, is proven by the presence of characteristic fossils of that formation almost to the very base of the series. Along the Gananoque road the underlying shales sometimes rest upon the beds of sandstone, which are sometimes reddish but generally gray in colour. They somewhat resemble the Potsdam sandstone in the area north of Brockville, but as a rule, are rather less siliceous. They are also well seen along both sides of the Rideau canal between Kingston Mills and Washburn, where they have a thickness of nearly fifty feet. Large outcrops of the sandstone are also seen around the shores of Dog lake in the township of Storrington, and at Battersea. The lower portion of the formation is frequently a conglomerate containing pebbles of quartz and sometimes of granite. As a rule the sandstones are in nearly horizontal layers, but sometimes, owing apparently to deposition on a sloping surface, the strata are inclined at an angle of ten to twenty degrees.

Age of the Kingston limestone.

In physical characters, the lower portion of the limestone formation north of Kingston resembles some of the limestones of the Chazy formation of the Ottawa district. They are highly dolomitic, hard and cherty, breaking with a sharp conchoidal fracture, and certain layers resemble a true lithographic stone. The lower part of the formation contains but few fossils, though organisms referable to the horizon of the Black River limestone are sometimes found. Among these, a species of *Leperditia* is somewhat abundant, and scattered forms of *Tetradium fibratum* also occur which serve to fix their position fairly well. The lower hundred feet contain interstratified beds of marly shales, sometimes several feet in thickness, while the upper part of the formation is a heavy bedded limestone filled with large fossils, such as *Columnaria Halli*, *Actinoceras Bigsbyi*, *Stromatocerium rugosum*, large masses of *Tetradium fibratum*, and other characteristic forms. The thickness of the entire series in rear of Kingston is somewhat over 200 feet above the basal beds of sandy and marly shale or arkose.

Thickness of Black River limestone.

At Kingston Mills on the Rideau canal, the contact of these rocks with the underlying granite and gneiss can be well seen about 200 yards west of the canal on the line of the Grand Trunk railway, where in a cutting there is a direct superposition of the green marly shales on the granite. These green basal beds near their contact with the granite are highly fossiliferous, the principal fossil as yet found being a small orthoceratite. To the east of the canal the limestones are seen along a road south of Rideau station, the rocks here having a low anticlinal structure, owing apparently to deposition upon a boss of red granite which is exposed near by. Black River fossils are here found down to the very base of the limestone. In this area no trace of the underlying sandstone is seen.

Contacts near Joyceville.

The outcrops of sandstone, already referred to as occurring along the canal above Kingston Mills, can be well studied at what is known as Gildersleeve's quarry on the east bank, about four miles above the locks. This deposit can be traced to the north-west as far as Joyceville corner, where the sandstone rests directly upon granite and gneiss, and dips S. 20° E. < 4°. The breadth of the sandstone along the road south of the corner, is several hundred yards and on this road it is directly and conformably overlaid by the Black River limestone, with interstratified shaly bands holding the characteristic fossils of that formation. The limestone here forms a low escarpment north of the road near a church, the dip being precisely the same as seen in the sandstone. It extends south-east for a mile and three-fourths, and at that distance is again underlain by the granite and gneiss, the sandstone not appearing in this direction, so that the limestone apparently occupies a shallow basin at this locality. Along the road down the east side of the canal, traces of the underlying sandstone are seen beneath the limestone, at a distance of about four miles north-west of the corner east of Kingston Mills.

Gildersleeve's quarry.

At the quarry the rock shows much false bedding, but some of the layers are massive and well suited for building stone, for which purpose it has been quarried somewhat extensively. The colour is in places a dark red, but in the upper part of the escarpment grayish shades prevail. In portions scattered pebbles of quartz occur and the rock forms a conglomerate. This rock resembles the sandstones of Potsdam age near Ottawa, and along the shores of Rideau lake, where it is directly overlaid by the Calciferous formation. It is soft when quarried, becoming hard after removal from the parent bed; in this respect resembling freestones of Carboniferous age. In the quarry several curious cylindrical concretions occur which resemble the trunks of fossil trees, and at one time they were regarded as such. They stand upright in the face of the quarry, the two principal ones having diameters of three and four feet, with an outer zone of three inches or more in concentric layers, corresponding to what would have been the bark if the structure had been organic. At the top of the cliff the upper ends of these concretions are slightly hollowed out, readily distinguishing them from the surrounding rock. The material of the cylinders is similar to that of the quarry rock. Numerous rounded concretions, from half an inch to two inches in diameter are found in the vicinity of the supposed trees, which by some persons have been regarded as the fruit. Rounded concretions of this kind are found in similar sandstones at the southern end of Knowlton lake.

Cylindrical concretions in quarry.

Unfortunately there is no fossil evidence from the sandstones themselves to fix their age, except the occurrence of certain markings resembling *Scolithus*, and this is not sufficient of itself to accurately determine horizons.

Age of the sandstones.

If we reject the early view of Murray as to the Potsdam age of these sandstones and classify them, on stratigraphical grounds, as a sandy local development at the base of the Black River formation, then it may be stated that no trace of the true Potsdam, Calciferous or Chazy formations has yet been recognized in the district west of a line from Gananoque to the upper Rideau lakes. This was the view apparently held by Mr. Eugene Coste in regard to similar sediments in Madoc and Marmora, which form part of the Palaeozoic outliers occurring there. On the map of that area, made in 1886, these were coloured by him as belonging to the Bird's Eye and Black River formations. Why the lower formations should not have been deposited throughout this western area is not clear, there being no apparent cause for their absence, since the Calciferous is extensively developed throughout the district extending north from Brockville to the upper Rideau lake, and thence eastward to the Ottawa, where it is in turn overlaid by sediments of Chazy age.

Development near Westport.

These sandstones have now been traced by numerous outcrops from the West Rideau lake near Westport, where they undoubtedly represent the western extension of the great Potsdam-Calciferous area of the Ottawa basin, southward to the St. Lawrence near Kingston. At Westport the sandstone rests upon the granite or other crystalline rocks, and passes upward through the Calciferous and Chazy formations into the Black River limestone. Along the Rideau canal south of Newboro', and in the area both to the east and west, while the sandstones and conglomerates present the same general aspect as is seen in the Rideau lake district, the strata of the Calciferous and Chazy, proper, appear to be absent entirely, at least in so far as has yet been ascertained, and the Black River limestone and shales rest either upon the sandstone or directly upon the crystalline rocks, with merely the occurrence of a thin deposit of arkose beds at their base.

Conformity to the sandstone.

The apparent conformity of the limestones to the sandstones can not be regarded as conclusive evidence that they all belong to the same series; since everywhere throughout the Palæozoic basin of the Ottawa and St. Lawrence rivers these sediments are generally in a nearly horizontal attitude throughout. Under the circumstances therefore or until more conclusive proof is furnished from the study of these rocks, we hold that it will be better to regard these basal sandstones and conglomerates as more properly belonging to the Potsdam sandstone formation, as originally suggested by Murray, than to the Black River limestone division.

Black River formation west of Rideau canal.

The outline of the Black River formation west of the Rideau canal, in the direction of Tamworth and Tweed, is somewhat irregular. At several points deposits of the green arkose occur, but the limestone often rests directly upon the crystalline rocks. The sandstones are rarely seen west of the line of the Kingston and Pembroke railway. They are however well exposed at several points in the townships of Loughborough and Storrington, and on the railway at a point about two miles north of Hartington station, there is a good contact of the limestones and the green shales upon the underlying sandstone, the whole series being a conformable one all the way upward from the contact of the latter on the granite. Around the shores of Dog lake in the former township, the sandstones are well displayed and at one point on the north side contain several large but pockety deposits of red hæmatite which have been mined to some extent. At Battersea also the sandstones are well seen on the red granite in nearly horizontal ledges to the north and east of the village, but on the south side the granite on the road is covered by the green arkose which passes directly up into the cherty limestone.

Contact at Battersea.

To the south of the road however, the greenish beds rest upon the sandstones which fill up irregularities in the underlying gneiss and granite. The gneiss at this place is very quartzose and in places rusty, and it has been penetrated by the granite mass.

Howe island.

On the islands lying in the St. Lawrence between Kingston and Gananoque, notably on Wolfe and Howe islands which are the largest, several good contacts are seen. On the north-east end of the latter, which is several miles above Gananoque, ledges of sandstone occur, in places resting upon the granite and filled occasionally with pebbles of white quartz. These are overlain by the green, gray and black shales, which are found at the base of the cherty limestones, near a small cove known as Bush bay, about two miles from the lower end of the island. The beds are all horizontal. Some of the shaly layers are very like certain green Chazy shales of the Ottawa basin, but are not quite so hard or slaty. They pass directly up into the limestone which contains Black River fossils. and which thence occupy the whole of the island along the south side. On a road across the island from Bush bay, the Black River limestone rests upon white quartzite about midway to the north shore. The quartzite is penetrated by red granite, and the latter is seen along the north side of the island below the mouth of Big bay. The south-west part of the island is all Black River limestone.

Contact of Black River limestone with quartzite.

Wolfe island.

On Wolfe island the Black River limestone is the prevailing formation. It is seen in low ledges along the shore where this is not occupied by clay or sand.

The northern part of the island is occupied by the cherty variety with shaly layers, but near the village of Marysville the upper portion of the formation is well seen and contains great numbers of fossils in which *Tetradium fibratum* is abundant. These rocks extend south of this to a point opposite the north end of Simcoe island, when they are overlaid by limestone of Trenton age. The rocks of the Trenton formation apparently occupy all the western end of the island and are well seen at Bear Point at the south-east extremity, from which a large collection of fossils has been obtained. The rocks of the island are all so nearly horizontal that dips cannot be measured.

Simcoe and Horse islands.

Simcoe and Horse-shoe islands off the west end of Wolfe island are both occupied by fossilferous sediments, partly of Trenton age. Garden island, which lies off the city of Kingston, is composed of Black River limestone. Further west, Amherst island and the whole of the peninsula of Prince Edward county, are apparently entirely occupied by the Trenton formation, which abounds with fossils everywhere.

Kingston and Adolphustown.

The Black River formation, seen at Kingston, continues westward along the shore of Lake Ontario as far as the village of Bath, where it is overlaid by the Trenton limestone. The latter thence extends across the peninsula of Adolphustown to Deseronto, where basal beds holding *Receptaculites* are seen in the bed of Sucker creek, about half a mile south of the Grand Trunk railway near Deseronto junction. The outline of the formation north of this is somewhat irregular and the Trenton limestone occupies basin-shaped areas upon the Black River to the north of Napanee, whence it extends north-west into Tyendenaga township. The Black River limestone shows in a bold escarpment on the west line of the township of Richmond, about six and a-half miles north of the Bay of Quinté and a short distance south of the crossing of Salmon river, whence the southern boundary of the formation continues south-easterly to the shore of the bay. The rocks are well exposed near Shannonville station on the Grand Trunk railway, where there is a boss of granite and quartzite upon which the newer limestone is deposited. The Black river limestone forms the north side of the Bay of Quinté at Ox Point, about three miles east of Belleville, and large and valuable quarries are here located in the massive beds near the summit of the formation. The opposite shore in Prince Edward county, at Massasauga Point, is of Trenton limestone. At Ox Point the strata are, in places, inclined at an angle of ten to fifteen degrees, probably indicating an underlying boss of the crystalline rocks.

Shannonville Station G.T.R.

Belleville.

The Trenton comes into view west of this place in a cove and is again seen at Belleville on the Moira river and northward along this stream for several miles, the exact contact with the Black River formation not yet being traced in this direction. From the Moira river the Trenton continues along the north side of the Bay of Quinté and is well seen in low-lying ledges in rear of the town of Trenton, which is just beyond the western limit of map-sheet No. 112.

Arkose beds of Rideau lake.

The arkose in the Kingston district differs somewhat from that seen along the shores of Rideau lake where it is well exposed along the south side near what is known as the Narrows. Here the Potsdam sandstone and the overlying Calciferous are well developed, but the basal beds in the lake district sometimes consist of a coarse conglomerate made up of pebbles of gneiss, granite, quartzite and crystalline limestone, some of which are at least two feet in their greatest diameter. All these pebbles are water-worn and are cemented by a sandy and calcareous paste. No conglomerates of this character have been recognized anywhere west or north of Kingston except at one place on lots 3 and 4, ranges VII and VIII, of Loughborough township, where a four feet bed of coarse conglomerate was recorded by Murray in 1852 as resting on crystalline limestone. The colour of the Potsdam sandstone around Rideau lake, as also of the sandstones in Kingston district, varies from red to gray, the former colour being due to red hæmatite which sometimes forms masses of considerable extent, capable of being locally mined. This hæmatite character is also seen in the Kingston area at several places, the ores being generally pockety masses, sometimes of large size, near the contact with the crystalline rocks.

Red hæmatite.

Crystalline rocks.

North of the area occupied by the Black River limestones the crystalline rocks are well seen. They consist of gneiss, quartzite, limestone and schists, the whole resembling what is known in the province of Quebec as the Grenville series and in Ontario as the Hastings series. They lie in a number of undulations and are broken across at many places by masses of generally red granite which are newer than the schist and limestone. Masses of dioritic rock, pyroxene, and large dykes of pegmatite are common throughout the area occupied by the crystalline series.

Surface deposits.

Along the contact in the vicinity of Tamworth are heavy deposits of sand, gravel and boulders which may represent in this direction the extension of what has been called the 'Iroquois beach' which is so well developed north of Toronto. No fossils have been found in any of these deposits, nor in the clays west of the Rideau canal.

Valuable mineral deposits are found in the district, more especially in connection with the crystalline rocks. In the Black River limestone, north of Kingston, there is a somewhat remarkable fissure extending across the country for several miles which has been filled with baryta, the thickness of the vein ranging from a few inches to over three feet in places. The mineral is grayish-white and has been opened up on lots 16 and 17, range IV, of Kingston township, and is seen also on lots 15 and 16, of range V. The vein crosses the lots in a north-east and south-west course. An interesting feature in this vein, which is vertical, is the presence of small quantities of anthraxolite in connection with the baryta.

Baryta vein near Kingston.

Anthraxolite was also noticed from a vein, apparently cutting red granite, at a point about one mile west of Chaffee's lock, on the north side of Opinicon lake. The material is very pure, almost pitchy in character, and ignites readily with a match. It is found in the debris thrown out by some animal in excavating through the drift at the foot of the granite ledge, the vein itself not being seen.

Anthraxolite.

The iron ores which occur in connection with the sandstone have already been referred to. The deposits of hæmatite are found principally at Dog lake, which connects with the Rideau canal a short distance north of Brewer's locks, and at several points along the north side of Opinicon lake. At the latter place borings have been made with a diamond drill to a depth of several hundred feet. The ores occur in the sandstone near the contact with crystalline limestone and the deposits appear to be pockety in character. Another deposit of red ore is seen near the road a short distance west of the lake on the north half of lot 13, range XIV, of Storrington. The outcrop here is uncovered for a space of about seven feet square and the extent of the deposit is unknown. The other deposit is on lot 2, range XIV, Bedford.

Iron ores.

The principal mining industry in the district at present is the production of mica. This mineral is found in connection with the pyroxene rocks at a number of places in the townships of Loughborough, Storrington and Bedford especially, and in the Rideau lake district in North and South Burgess and South Crosby.

Mica deposits.

Mining has been carried on for a number of years at various points in the district, and a study of some of the principal deposits was made for the sake of comparison with those which occur on the north side of the Ottawa. The conditions appear to be the same in both these mining districts. The principal deposits are found in two forms, viz., in fissures in the pyroxene itself, where the mica crystals occur often in large masses, apparently segregated from the containing rock, in which case, calcite so often found elsewhere in association with mica is almost entirely absent; and secondly, as contact deposits in the

Mode of occurrence of mica.

pyroxene, near the junction with the gneiss rock, in which case the mineral is usually associated with more or less calcite. Good illustrations of the latter mode of occurrence are seen at the Stoness mine near the lower end of Buck lake, on lot 4, range XII, Bedford, where an inclined shaft, which is on a slope of 45 degrees, has reached a depth of about 450 feet and where the rock of the dump from the principal mine is almost entirely composed of calcite. At this mine several cross dykes of dark diabase cut the deposit.

General Electric Co's Mine, Sydenham.

Of the fissure type of veins, that of the General Electric Company near Sydenham, on lot 2, range VII, Loughborough, is a good example. Here calcite is almost entirely absent in the dump, and the pyroxene, which is of a light green colour, forms a large dyke cutting transversely across a grayish and sometimes rusty gneiss. On the south-west side of the main pit there is a heavy dyke of hard blackish diorite rock or a dark hornblende granite which in some parts gives place to a pinkish red. This forms the foot-wall of the principal vein, which here dips to the northeast at an angle of 60° to 70°. The vein consists of masses of crystals of amber mica, often of large size, some of them being as much as five feet across the face. It is generally of excellent quality and comparatively free from fractures. The thickness of this deposit is from ten to fifteen feet. Along the foot-wall are occasional small lenses or patches of calcite, pinkish or gray in colour. The mica deposit is therefore of very large size, and the vein appears to fold over the crest of the large diorite dyke. Small quantities of green apatite are found in the pyroxene.

The McLaren and Fulford mine, South Crosby.

At the McLaren and Fulford mine east of Davis lock, on lot 15, range VII, South Crosby, which was opened some twenty years ago as an apatite mine, and re-opened in 1900 for mica, the country rock is a reddish-gray gneiss, much intersected by granite. At the opening there is a heavy dyke of dark hard diorite which intersects the pyroxene, and in the excavation the mica vein sometimes widens to a thickness of eight to ten feet, many of the crystals being of large size. Bunches of iron pyrites are found in places near the edge of the vein, and when this occurs the good quality of the mica is seriously affected, it becoming much broken and discoloured. Apatite, both red and gray in colour, occurs in some abundance and there is a small quantity of red hæmatite in parts of the excavation. Small bunches of pink calcite also occur. The output of mica is large and its quality fairly good.

Tett's mica mine.

At Tett's mine, which is about three miles from the upper end of Devil's lake, on lot 2, range VIII., Bedford, the country rock is also a reddish and reddish-gray gneiss with bands of rusty gray gneiss, the strike of which is about N. 50° E. and the dip to the north-west. This is cut by a heavy dyke of light-green pyroxene which is in turn cut by a very hard grayish granite. The mine is opened by a series of pits in the pyroxene, but as unfortunately these were filled with water at the time of our visit, the relations of the mica could not be clearly ascertained. The output is, however, stated to be very considerable, and the crystals of large size. There is but a small showing of calcite at this place, and the pyroxene cuts directly across the strike of the gneiss, the mica occurring apparently as a contact deposit near the junction of the gneiss and pyroxene. Bunches of iron pyrites occur in the hard pyroxene and the course of the dyke is about north-east. Large crystals of pyroxene are found at this place.

Smith and Lacey mines.

At the Smith and Lacey mines on the north side of Opinicon lake, the country rock is largely a rusty gneiss which is cut by several dykes of pyroxene, some of which are of large size. No pink calcite was observed at this place, but there is an abundance of light greenish-gray rock, apparently a felspar on the dumps. The mica is of large size and good colour and apparently very abundant at some of the openings, but as no work was being carried on at the time of our visit the chances for observing the relations were not very good. The mica appears to occur in fissures in the pyroxene.

The above descriptions of the leading mica deposits serve to show that the conditions at these mines are almost identical with those already described as occurring in the area north of the Ottawa. There are a number of other deposits in the district, some of which appear to be of excellent quality, but these were not examined owing to the lack of time.

Iron deposits of the Kingston district.

The iron deposits are of two kinds, and have been well described in the report by Mr. Ingall on the ores of the Kingston and Pembroke district. It is not necessary to refer to them in detail in the present summary. Of these the magnetites are associated with the crystalline rocks, generally in connection with masses of intrusive rocks, which cut the gneiss and limestone of the district. The hæmatites, on the other hand, are usually found associated with the sandstones, which have been already described. They are of a different origin, and some of them have already been referred to on a previous page.

Felspar deposit of 13 Island lake.

In connection with a number of the granite dykes which everywhere abound in the area of the crystalline rocks, notably in the pegmatites, large masses of pink felspar are found. Among these the most important yet noted are at a locality on lot 1, range II, of Bedford, near the shore of Thirteen Island lake. The felspar from this location is beautifully clear and apparently largely free from iron. It is quarried and shipped from Bedford and Verona stations, on the Kingston and Pembroke railway. The quantity is said to be almost unlimited. The distance of the mine from Bedford, by winter road, is about four miles, and from Verona, by the regular road, about seven miles. Other large deposits of this mineral occur in the vicinity. The principal mine has been worked by Richardson and Smith.

Felspar of Kingston mills.

Another similar deposit of felspar occurs in the granites near Kingston Mills, and it has been worked to some extent. The quality at this place is also excellent.

Lead mines.

No new developments have been made in the lead deposits, of which several are found in the townships of Lansdowne, Bedford and Loughborough.

Talc.

A deposit of talc has recently been opened and mined to some extent near the road from Gananoque to Kingston and about three miles from the former place. Work on the deposit of this mineral on one of the islands, in Rideau lake, a short distance from Portland, has been discontinued.

Limestone quarries.

Large and valuable quarries have been opened in the limestones of the Black River formation at Kingston, Wolfe Island, Napanee and a number of other points throughout the district. At Deseronto, a large quarry is located in the Trenton limestone about a mile north of that town. The quarry at Ox Point, near Belleville, in the upper part of the Black River formation, has already been referred to.

Sandstone quarry.

The sandstone of Gildersleeve's quarry on the Rideau canal furnishes an excellent building stone. Some of the output has been shipped to Montreal, and a number of houses and public buildings in the neighbourhood of Kingston have been constructed either wholly or in part of this stone. The effects of the red stone in combination with the gray limestone is very good. At present the quarry is not worked.

Copper, gold, actinolite, zincblende.

Mines of copper and of gold have been opened in the neighbourhood of Flinton, in the northern portion of the area. No work was being done at these during the past season. A deposit of actinolite has been worked to some extent near the road between Flinton and Kaladar, and a number of tons of the mineral have been extracted. A deposit of zincblende occurs in Olden on the north side of Long lake, from which about 100 tons of ore have been taken.

Shell-marl.

Shell-marl is found in the bottom of many lakes throughout the area north of Kingston. A large part of Loughborough lake is underlaid by this substance, more especially in the western half. In Mr. Murray's geological report for 1852–53, it is stated that the bottoms of all the lakes from this to White lake in Olden, are more or less of the same substance. It was also found in White lake in Sheffield, and on the brook which flows from it to Beaver lake; but the largest and 'most available deposits met with were on Mr. McDonnell's property, on the 15th and 16th lots of the second concession of Sheffield, and on the 12th lot in the third and fourth concessions of the same township. The deposit on Mr. McDonnell's place, extends over an area of 200 acres and perhaps more, with a thickness over the greater portion, of at least ten feet, which was proved by pushing a pole of that length through it in various places, without striking any other material. On the surface there is a thin soil, bearing a luxuriant growth of prairie grass. Mr. Murray says:—

Deposit in Sheffield township.

'The marl on the 12th lot of the third and fourth concessions, extends over at least 300 and perhaps 400 acres or more, but its thickness I could not ascertain. The place where it occurs is mostly a marsh or swamp, and the deposit is covered over by an accumulation of peat, averaging about four feet in thickness.'

Mr. A. Murray quoted.

A large deposit of marl of excellent quality which occurs near Marlbank in the township of Hungerford, has been used for some years in the manufacture of Portland cement. The marl occurs in the dry bed of a lake with an extent of about 150 acres and a depth in places of not far from thirty feet. The cement works are located in close proximity to the deposit at Marlbank, but a second manufacturing plant has recently been established at Strathcona, six miles east of Napanee on the line of the Bay of Quinté railway, the raw material being brought from Marlbank. This location is admirably adapted for the purposes of manufacture, being near the line of railway.

Marl deposit at Marlbank.

PETROGRAPHY OF SHEFFORD AND BROME MOUNTAINS.

Principal J. A. Dresser.

In accordance with the plan of the Geological Survey to complete the petrographical examination of the series of remarkable volcanic hills which crosses the St. Lawrence valley from Shefford and Brome to Rigaud, investigations have been continued during the past season on Shefford and Brome mountains. The unusual character of these hills has been mentioned in several earlier reports of this Survey, especially those for 1863 and 1894, but it is only recently that detailed petrographical examinations have been begun.

Petrographical investigations by Prof. J. A. Dresser.

Work facilitated by private investigations.

This work is likely to be greatly facilitated by private investigations. Mr. O. E. LeRoy, B.A., McGill University has already presented the results of a very complete examination of Rigaud mountain to the Geological Society of America at the winter meeting of 1900. Therein he shows that this mountain is more likely connected with the porphyry intrusion at Grenville than with the present series. A petrographical description of Mount Johnson of this series by Dr. F. D. Adams will soon appear, while similar work at the hands of Professors Harrington and Adams has been in progress at Mount Royal for some time. Mr. LeRoy has also the examination of Belœil mountain well under way. There remain therefore Yamaska, Rougemont and Montarville yet to be studied; also Calvaire, should preliminary investigations prove it also to belong to the series. In all cases, the results of these detailed researches have shown that these hills are of rare geologic interest.

Shefford mountain report.

The report on Shefford mountain has been completed and was placed in your hands in May last, while in the months of July and August, the field-work necessary for the completion of a similar report on Brome mountain was carried out. In previous summary reports it has been stated that Shefford mountain is an elevation covering some nine square miles in area in the county of Shefford. It has been caused by three successive volcanic eruptions, the lavas of which have formed rocks of rare types in each case. A careful microscopic study of over one hundred specimens of these rocks has been made, and also a complete chemical analysis (by Mr. M. F. Connor, B.A.Sc., Radnor Forges, Que.) of one of the main types. The first (in point of age) of these igneous rocks is found to be essexite. It forms two masses in the mountain, the later rocks having probably been thrust up through the original body, thus dividing it into two parts. One comprises the locality of Coupland's lake and thence extends northward to the edge of the mountains near Shefford Mountain post office. The other extends along the margin of the mountain from Beauregards corner to McCutcheons road and includes the important rock of Morriseau's quarry.

Igneous rocks.

The second rock is a variety of syenite distinguished as Nordmarkite in its type occurrence, which is in southern Norway. It forms all the marginal part of Shefford mountain not occupied by essexite. A contact phase of this is the rock at Dounan's quarry, which proves to be of unusual value for monuments and other decorative work for which granite or syenite is commonly employed. The possibilities of this quarry were mentioned in a summary report for 1900. Since that report was written, however, the quarry has been acquired by Mr. C. J. Hill, of the Granite and Marble Cutting Works, of Richmond, who has in a couple of weeks' preliminary work already taken out a quantity of

Dounan's quarry.

material which, when polished will have a value of about $3,000. From the success thus met with Mr. Hill contemplates the dressing of the rock at the quarry and possibly the erection of polishing works there as well. Other portions of both these rocks seem to be well suited for economic purposes.

The third rock is pulaskite, also a rare syenitic type. It forms a smaller part of the mountain and extends from Coupland lake south-eastward over the highest point above Knotts corner. It here terminates in a point at the south, being scarcely two hundred yards wide where crossed by the mountain road. A summary sketch of the rocks of Shefford mountain was published by your permission in the October number of the *American Geologist* of the current year.

Area of Brome mountain.

Brome mountain embraces an area of about thirty square miles in the townships of Brome, East Farnham and Shefford, which belong respectively to the counties of Brome, Missisquoi and Shefford. The central portion in the vicinity of Brome pond consists of a rather level basin about two and a-half by two miles in extent, which is generally overlain by heavy beds of clay, and is surrounded by a nearly continuous rim of hills rising from 600 to 1,000 feet above the level of the surrounding country. At West Shefford station this level is 440 feet above mean sea-level. The interior is well cleared, while the hills are all wooded; yet, as most of them are used for pasture lands, the highest points were generally found well enough exposed to afford fairly satisfactory conditions for geological study.

Drainage of area.

The drainage of almost the entire area is towards the south-west. Brome pond, a small sheet of water some three-quarters of a mile in length and half as wide, lies in the lowest part of the interior basin, and is drained into the Yamaska river through an opening in the hills known as Glen Farnham. No definite information was obtained as to the depth of the pond. Fed by a brook whose dimensions are not much less than those of the outlet, it must be largely a drainage lake. Yet, as it lies at the contact of two different igneous rocks, and as springs are common along these contacts, the pond probably derives some of its waters from underground sources. Two other ponds, known as Gales and Silver spring or Bull's pond are each about half as large as Brome pond. They have much smaller drainage basins, with much less sediment along their banks, and are presumably more largely fed by subsurface inflow.

Earlier reports.

In the earlier reports which have been referred to, it has been shown that Brome mountain is of igneous intrusive origin. The surrounding sediments have been shown by Dr. Ells, in the annual report of this Survey for 1894, to belong to the Sillery division of the Cambrian system and to the Phillipsburg series (D 2 b) of the lower Trenton.

The mountain was first crossed in two directions, first, from West Shefford village to the 'centre road' between Sweetsburg and Knowlton, and next from Tibbetts hill to Gale mountain, thus giving two complete sections across the area. The contact with the enclosing sediments was next traced out as carefully as possible, and finally the different rock masses which comprise the igneous part of the mountain were separated from one another. Representative specimens were taken from all parts of the mountain, of which thin sections are in course of preparation. Three analyses of the main or representative types are now being made by Mr. M. F. Connor. I must acknowledge with warmest thanks, the valuable help received from Mr. H. A. Honeyman, M.A., Knowlton, in the latter part of the field-work.

Composition of mountain.

The mountain consists of two principal rock masses of different ages of intrusion, with a smaller area of distinct character and probably also of different age. The earliest is a dark-gray rock weathering dull brown. In texture it is coarsely holocrystalline and frequently has a porphyritic structure. Felspar, hornblende and biotite are the principal constituents that can be distinguished in the hand specimen. In general aspect it resembles the theralite of Mount Royal in places, and in others the essexite of Shefford mountain. Flow structure is sometimes found. This rock forms the south-western part of the mountain from the vicinity of the Iron Hill Cemetery to a distance of half a mile north of Gale pond. It skirts Brome pond on the south-west. A mass, which is apparently separate, runs from Colliers hill for a mile and a-half towards Shefford station. Probably a part of the same original occurrence, it is either cut apart by the irruption of later rock, or covered in the intrusion of the latter. The contacts are so far concealed as to make it difficult to determine which has been the case.

Second variety of igneous rock.

The second variety of igneous rock forms the northern part of Gale mountain, Oak Hill, the vicinity of Hayes' quarry, Spruce mountain, Pine mountain and Tibbetts hill. It is a fawn-coloured or light-gray rock, in texture very coarsely crystalline. Felspar, and a small amount of a green bisilicate are the chief constituents of the rock. In places, however, nepheline can be seen by the unaided eye. A single microscopic section from the farm of Nelson Keet and near the head of Brome pond shows the felspar to be microperthite and the bicilicate algerine-augite. Both are embedded in nepheline, which is here scarcely perceptible without the aid of the microscope. Pegmatitic structure is common in this rock, while certain parts are porphyritic. It has been used in the construction of the Canadian Pacific railway bridge over the Yamaska river near Sheffington, and also of the Roman Catholic church at West Shefford. In those parts of the mountain which have easy railway access it should eventually prove a valuable material for ornamental and constructive purposes. Its close resemblance to the laurvikite of Norway, which is much used for interior decorations on the continent of Europe, is important. The favourable railway communication of this locality, together with the various kinds of rocks suitable for ornamental purposes in Shefford and Brome, should give rise to a 'granite' industry at West Shefford, comparable to that of Quincy, Massachusetts, or Barre, Vermont. Some of the pegmatitic phases might be found useful for the production of felspar for pottery manufacture. Where protected from glaciation, this rock has commonly disintegrated to a depth of several feet and the weathered material, being generally somewhat uniform in size and always angular in form, makes excellent road metal. Large quantities are thus available at many points, a fact of which the Good Roads Association of the township of Brome would do well to avail itself. The name 'Iron Hill' does not appear to find justification in the presence of any considerable quantity of that metal. The name has probably been derived from the limonite coatings common on the joint planes of the syenite of the vicinity.

Probable economic value of granite.

The third rock type occurs on the road between West Shefford village and Brome pond, and is in part on the farm of John Jones. It extends for a quarter of a mile east of the road and, by greater resistance to erosion, forms a low and rather flat-topped hill. It is a greenish-gray rock and porphyritic in structure, the phenocrysts being probably felspar. The rock has the general appearance of a tinguaite, but its identification is as yet by no means definite, as no detailed study of it has yet been made. Its relation to the other igneous rocks is not clear, as the contact is concealed in all cases as far as could be found, either by drift or, in larger measure, by sedimentary outliers, which have been protected from removal by the greater durability of the rock already mentioned. Completely surrounded by the syenitic rock just described, this tinguaitic rock differs from the latter in being of an effusive, or hyperbyssal, rather than of a plutonic character. While it may be a more rapidly cooled part of the larger mass, it seems more probable that it forms a separate intrusion.

Third rock type.

Although the character of its crystallization might be regarded as indicative of the extension from an active volcano, of which this point would have been the vent, the presence of sedimentary outliers in many parts of the mountain and even at higher levels, as on Pine mountain, seem to indicate unmistakably that Brome mountain, like Shefford, is an uncovered lacolith and has never been an active volcano.

Brome mountain never an active volcano.

GEOLOGICAL EXPLORATION OF ANTICOSTI.

(The Very Revd. Professor Laflamme.)

(Translated from the French.)

Work by Rev. Prof. Laflamme.

The geological study accomplished at Anticosti during the past summer extends from English Head to the north as far as Pavilion river to the south-west, that is, it covers a distance of slightly over 100 miles. All the observations here recorded, therefore, only apply to that part of the shore. The remainder will be taken up later in another report, if circumstances permit. As to the geological study of the interior, that is to say, going up the rivers and making sections, I had to give it up this year owing to the clouds of mosquitoes which swarm in that part of the country even at the end of August, and which render any continuous work very difficult. This could better be undertaken in September and October, towards the end of the season.

Stratigraphy of the island.

General stratigraphy.—This is to be found described in a very detailed form in Mr. Richardson's report for 1856 and in the geology of Canada for 1863. The very full and detailed sections which are there given should not, however, be taken too literally. The composition of the different strata of any one group, their attitudes and thicknesses, vary to such an extent at different places, that unless work is done at the exact spots where they were determined by the geologist of 1856, notably dissimilar results and conclusions would be arrived at.

It is true that the main divisions are such as they were then determined to be, but we had to give up going into a superabundance of secondary details of too numerous subdivisions. To generalize in too absolute a fashion would be laying one's self open to errors.

All the beds of the island from one side to the other lie conformably to each other, almost horizontally except for a very slight dip, hardly noticeable, towards the south or south-west, but sufficient to account for the difference in appearance between the north shore and the south shore of the island.

Abrupt cliffs.

The rocks on the north side form quite abrupt cliffs, which rise in places to more than 500 feet; those on the south shore are low lying, rising but little above the level of the St. Lawrence, except in a few cases, owing to local faulting.

Nowhere have I noticed folds or bends of any importance, except the very low anticlines revealed by sections along the shore above the Jupiter and Lachute rivers.

Two important faults.

However, two rather important faults occur in that part of the shore which I examined. One is seen at Cap-à-l'aigle (Ellis bay) and extends parallel to the shore at a certain distance from it beyond Rivière-aux-Canards. On the north side, this line of fault is disclosed by an abrupt cliff, and on the south side by a string of small lakes found at its foot. At the latter point the shore has been formed by the action of the waves depositing the débris torn from the partly covered beds. The second fault is found at Jupiter river. It crosses the shore obliquely one mile above its mouth at the western extremity of Cape Jupiter. From that point it crosses Jupiter bay and disappears on the shore of the West Point. The southern wall is lower than at Cap-à-l'aigle; it sinks under water and the waves have hollowed out Jupiter bay from the northern wall, which rises into a cliff. At this place the northern cliff rises to a height of some 200 feet.

This faulting was not accompanied by any changes in the regular disposition of the beds. The strata remained horizontal on both sides of the break.

Hudson River limestones.

All the strata seen on the island are limestone, with the exception of some thin and irregular layers of sandstone at Pointe aux Graines, Riviere aux Canards, and Riviere Becsies. The Hudson River beds themselves, which form the whole northern shore from West point as far as Baie aux Renards are also limestones, but the latter are more argillaceous than those on the southern side. Imbedded in these are large corals impregnated with petroleum to such an extent that on breaking them the oil oozes out. The presence of these petroliferous fossils might lead one to hope that this valuable liquid may sometime be found in quantity on Anticosti island, but this is not very probable. The corals referred to are only met with in the Hudson River beds along the north shore. No physical disturbance has affected these strata, which are everywhere horizontal, and there are no reasons for the belief that crevices or cavities exist in them to act as reservoirs in which the petroleum, scattered throughout the mass, would in time have collected. Moreover, these corals are not abundant and the calcareous beds which contain them do not present the bituminous character found in other places, as for example in the vicinity of Quebec city or at Lake St. John.

Glacial phenomena.

The rocks of Anticosti are very often exposed on the tops of hills. In the lower parts they are concealed by a greater or less thickness of gravel and calcareous detritus of modern origin. At different places are found varying thicknesses of stratified clay, with fossils similar to those found in post-glacial clays in other parts of the province. Their surface is covered by a layer of silicious sand, also stratified, but devoid of fossils. These argillaceous beds cover a part of the western side of the island, where they are put under cultivation. They also appear very distinctly as river terraces at Cap Ste. Marie, and also from Rivière du Cap as far as Rivière Pavilion. Unfortunately these argillaceous deposits are not likely to extend very far into the interior, except at Lake Plantain and vicinity. Moreover, at a short distance from the shore, they are covered by a thick layer of mould which would render their availability as farming land very problamatical. Nowhere are these quaternay deposits as thick as in the great central plain of the province of Quebec.

As a rule the rivers of Anticosti have completely removed these argillaceous deposits and have eroded them to the rock over which they flow, and this in spite of the restricted volume of water which they discharge, so that their erosive power is comparatively small.

Clays of post-glacial origin.

These clays are post-glacial. The fossils which I found contained in them, and of which I have sent you specimens, amply prove this. The numerous pebbles which they contain are all calcareous, with sharp angular edges and are almost all derived from the rocks of the island. Moreover, the eminently calcareous character of the clays themselves is a proof that they are the result of the decomposition of the strata found on the island, that they were formed almost entirely 'in situ' and that the older rocks on the north shore had very little or nothing to do with their origin. Therefore all the farming soil of Anticosti seems to me to be of local origin. The great scarcity of siliceous sands may thus be accounted for, the formation of the island containing very few beds of sandstone and no other siliceous rocks.

Glacial striæ scarce.

The glacial striæ are very scarce on the island, owing to the calcareous nature of the rocks, which weather easily. I found, however, a few very distinct ones at Rivière du Cap, which had been protected by a bench of sandy clay some twenty feet in thickness. Their direction is from north-east to south-west.

Moreover, evidences of glacial action are very apparent on studying the pebbles and boulders which are found in every part of the island, even on the highest points. These pebbles are everywhere numerous, some of good size and rather well rounded. They consist of fragments of gneisses, granites, pure labradorite, and other rocks, which evidently come from the north. These pebbles together with the evidence afforded by the glacial striæ already referred to, constitute an undeniable proof of the passage of the ancient land ice over the surface of the island.

That the waters of the subsequent period (Champlain) covered the island of Anticosti is amply proved by the presence of the fossiliferous terraces of arenaceous clay, as well as by numerous calcareous pebbles with marks of burrowing by *Saxicava*, etc., which are also found everywhere on the island, both in depressions and on eminences.

Uplifting distinctly marked.

The uplifting which characterized the close of this period throughout the province is distinctly marked on the island. Two phases of it may be recognized; they are clearly shown by two systems of terraces which are noticeable at two different levels between the St. Marie and Jupiter rivers. One of these is found at a height of about fifteen feet and the other at some thirty feet above the level of the St. Lawrence. This uplifting is still going on, and appears to be taking place with remarkable rapidity. This is proved by the deposits of gravel which form the subsoil of a great part of the island between Ste. Claire Bay and Strawberry cove, as well as the apparent filling up of Ellis bay.

The gravel is of contemporaneous origin, as benches of it are in course of formation on the rock beaches along the shore (on the 'reef,' as it is called on the island), wherever the combined action of the wind and currents favours it. I believe it is shown beyond doubt that the deposits of the Champlain period had not invaded a certain number of the bays, these being filled in later by the debris derived from the different beds and moved about by the action of the waves.

Ellis bay filling up.

Ellis bay is distinctly being filled up. Lake St. George, situated on the north-east, has just been connected with it by an artificial waterway. These two were formerly connected underground, the lake forming originally a sort of lateral extension of the bay, the uplifting of the surface which took place later separating them. At the bottom of the bay, near the dwelling place of the famous smuggler Gamache, there was, within the memory of man, a small harbour where large row-boats could take shelter. This no longer exists, the harbour being almost completely dried up.

Rock beaches extending.

The keeper of the western lighthouse (Mr. Malouin) states that the rock beaches, which are uncovered for more than a mile at low tide, appear to extend further out from the shore every year, as if, as he expresses it, the water of the St. Lawrence was slowly receding year after year.

I have seen almost everywhere, from Bay Ste. Clair to Otter river, shore deposits at levels much above those now reached by the highest tides. At Grain point these deposits extend over an area of several acres. Their surfaces are covered by long wave marks which are all parallel to the shore line. Similar marks are found at several places on the island at short distances from the shore, and hunters who have lost their way in the bush refer to them to get their bearings, experience having shown that by walking at right angles to these marks they will eventually reach the shore. All these facts tend to show that at least the north-west part of the island is even now undergoing a movement of uplifting, and this at a comparatively rapid rate. This elevation goes on to such an extent that in my opinion it will have to be taken into account when it becomes necessary to determine the harbours and sheltering places on the coast.

Island covered with peat.

It may be stated that the whole of the island is covered with peat, which is always very coarse on the surface. This peat is composed of a mass of vegetable debris barely decomposed, in which the organic structure remains quite visible. At Ellis bay, however, a bed of black peat occurs much older than the surface deposits. It is found under a layer of clay and gravel over ten feet in thickness.

Trees of fair size.

The peat of Anticosti, when mixed with a small proportion of clay or of marl, constitutes a wonderfully fertile soil, in which vegetables and cereals can be grown to perfection. The trees also attain good dimensions but in places where the peat lies immediately over the gravel or on bed-rock, it constitutes too thin a soil and the trees do not, in such places, attain their full development, but remain dense and small. Still wherever a layer of peat, a couple of feet in thickness, rests directly on a marly or clayey subsoil, the trees are found of normal size.

Peat-bogs, proper, abound on the island. It may be said that they occupy the whole surface from East point as far as Salt lake. It has not been possible for me, owing to the short time available, to determine the exact extent or value. It can, however, be asserted that the aggregate of these areas is enormous and the deposits may be said to be inexhaustible.

Small lakes numerous.

Lakes are numerous on the island but none are of any great size. All, or nearly all, have the bottom covered by a thick layer of white calcareous marl, containing great quantities of fresh-water shells. But the chemical action of the aquatic plants is one of the principal agencies in its formation, and the material is evidently derived originally from the calcareous beds of which the island is composed. This is distinctly shown by the studies and experiments of Dr. Schmidt, physician at Bay Ste. Claire, the results of which were published in 'Le Naturaliste Canadien' of December, 1900.

This marl may be seen in places all along the shores. It is very easily recognized at a distance owing to its clear white colour, which contrasts strongly with the dark tints of the underlying beds of limestone and of the overlying peat. Wherever it is present wild plants and flowers grow exceedingly well and attain much larger dimensions. This feature is specially noticeable between Grain point and Duck river. Marl.

From what has just been said, it may be gathered that the soil of Anticosti is very variable from the farming standpoint. The peat or humus which almost everywhere constitutes the surface, forms a very fertile soil, the quality of which should not decrease or become exhausted when it overlies a clayey subsoil. But wherever it rests upon solid rock or gravel deposits, it may be expected that farming will become more and more difficult, unless great quantities of fertilizers are used. Soil variable.

Economic Minerals.—Besides the coarse limestone which can be used almost everywhere for the production of lime, large quantities of a pink crystalline limestone are found between the South-west point and Pavilion which probably would take a fine polish and could be used as an ornamental stone. This limestone abounds in crinoid stems which are completely mineralized of a reddish tint, darker than the background, and would present a very pleasing appearance when polished. Of course the economic value of these deposits cannot be definitely ascertained without some preliminary work, with the view of testing the lower beds to see whether the quality of the stone improves in depth. Economic minerals.

Other crystalline limestones are found to occur in the vicinity of South-west point; these are bluish-grey in colour and would make very good building stone. Moreover, I was told that beds of sandstone occurred on the south-east shore of the island, which could be used for the same purpose. Crystalline limestone.

On the Galiote, at about one mile from the river shore, my assistant found large deposits of pyrite. Pyrite is also found in thin sheets in the limestone beds which extend along the shore at the 'Jumpers,' about four miles below the South-west point lighthouse. Deposits of pyrite.

No trace of limonite or galena was found. The rocks of the island do not contain enough iron to warrant the hope of ever finding deposits of limonite.

Forests and Timber.—As a rule the trees on the island of Anticosti do not attain as large a size as they do in the more southerly and westerly parts of the province of Quebec. Along the shores, owing to the influence of the violent winds which blow towards the interior, the trees are almost everywhere stunted, with the branches bent and Timber.

entangled, and so thick that it is often very difficult to make any headway through them. In the interior of the island the trees are not so close together and are better developed. Certain areas may be considered as timber lands, though it is doubtful if large quantities of timber can be obtained. But wood which can be used for the manufacture of pulp is present in great quantities.

The following species have been recognized: *Abies balsamea*, *Betula papyracea*, *Larix Americana*, *Alnus rubra*, *Viburnum opulus*, *Abies alba*, *Abies nigra*, *Populus tremuloides*, *Sorbus Americana*, *Thuya occidentalis*, *Corylus rostrata* and several species of willows. Explorers who went into the interior of the island during the autumn season state that the trees found there are of much larger size. Besides the above kinds, they report the presence of *Pinus strobus* and *Fraxinus Americana*.

Second growth of trees.

In 1884 or 1885 a bush fire swept over a part of the north shore of the island. The trees which were then destroyed have been replaced by poplar and birch.

As to herbaceous plants, I hope to be able to send you a list of these later on. Dr. Schmidt, already mentioned, who devotes a great deal of attention to botany, has begun a herbarium composed exclusively of the plants of the island. His collection already numbers several hundred specimens, and he has very kindly promised me a list of the plants obtained, which list I shall forward to you.

Fur bearing animals.

There are very few species of land mammals on the island. The following are the only ones met with: black bear, red, black and silver fox, otter, marten and a very small rodent. Mr. Menier, the owner of the island, has gone to a great deal of expense in importing and placing on Anticosti, moose, cariboo, Virginia deer, beaver and even buffalo, in the hope of acclimatizing them and enriching the island with game. But the experiment is as yet of too recent date to be able to judge of the ultimate results.

I cannot conclude this brief report without acknowledging the kindness with which I was greeted by the proprietor of the island and his head employees. They were ever willing to give their help with the utmost readiness. Mr. Commettant, governor of the island for Mr. Menier, Abbé Tremblay and Dr. Schmidt in particular were a great help to me. Dr. Schmidt kindly added to my collection of fossils several species which I had been unable to obtain and which he had found in the course of his excursions. I am glad to have an opportunity to publicly offer them my most sincere thanks.

NEW BRUNSWICK.

Professor L. W. Bailey.

I have the honour to submit the following Summary Report of geological explorations made by me during the past summer in the Province of New Brunswick. Work by Prof. L. W. Bailey.

In a similar report submitted the previous year, it was announced that in connection with the study of certain Silurian rocks, reported by Mr. W. J. Wilson, of the Survey Staff, in the Parish of Canterbury, York county, where previously only Cambro-Silurian strata were supposed to exist, fossiliferous strata containing graptolites of Upper Cambrian age had been found by the writer in the valley of Eel River, near Benton, Carleton county. One of the objects of insvetigation in the season just closed, was, by your direction, the separation of the Cambrian and Silurian rocks in the district referred to, and the determination of the limits of each.

For the purpose named, I made a very careful review of the section afforded by the St. John river between Woodstock and the great central granite range of York county, as well as of the country lying to the westward of this stream as far as the International boundary. In the prosecution of this work I was, for a few days, accompanied by Dr. G. F. Matthew, of St. John, and to his intimate knowledge of the Cambrian system, in all its various aspects, as well as its contained organisms, I am indebted for very valuable assistance, as I am also for the benefit of his great skill in the solving of different stratigraphical problems. Section reviewed.

The following letter, addressed to me by Dr. Matthew, well expresses the nature of the problems referred to, as well as some of the directions in which their solution was sought. Letter from Dr. Matthew.

ST. JOHN, N.B., October 8, 1901.

'Prof. L. W. BAILEY.

DEAR SIR,—Having visited with you some of the more important sections of the Cambrian and Silurian rocks in York county, I would offer the following suggestions bearing on the possible structure and age of the early Palæozoic sediments in that part of the province. These remarks are made chiefly in paralleling the strata of the district above referred to with the known Silurian and Cambrian rocks of the southern counties of New Brunswick.

Synclinal structure in northern York County and Carleton County.

'*The Border of Carleton and York Couuties.*—It appears to me that the structure of the strata in this district is related to two synclinal folds, the axes of which diverge at a considerable angle from Monument Settlement on the western border of the province. One of these runs about N.N.E., mostly west of the provincial boundary line in the State of Maine, but crosses into New Brunswick northwest of Woodstock. The other proceeds east from Monument Settlement crossing the St. John at or near the mouth of Eel River.

Cambrian slates of southern Carleton Co.

'*Cambrian.*—' North of the axis of the syncline last named the strata appear to be Cambrian. At Benton and extending east and west from that village, there is a belt of black and dark grey slates which would correspond to the Bretonian division of the St. John group in the nature of its sediments. In this belt, at Benton, you have discovered a *Dictyonema* which I cannot distinguish from *D. flabelliforme*, Eichwald, a well-known fossil of the Upper Cambrian. There are here also obscure remains of trilobites, of which one appeared to be the pygidium of an *Agnostus*, and another a pleura with a shape and groove like that of *Parabolina* and its allies.

'North of these dark shales and extending as far north as Woodstock, is a large body of gray slates and quartzites that, in texture and appearance of the beds, may be compared with the Johannian division of the St. John group. Like that division of the Cambrian of the southern counties also, it contains burrows of *Monocraterion*. Other pits observed on the surface of the layers were those of *Arenicolites*. Such burrows, however, might be found in strata of later date than the Cambrian.

Ordovician fossils of Beccaguimic river.

'That this belt of rock is Cambrian seems to be shown also by the occurrence of Lower Ordovician fossils in it on the Beccaguimic river, north-east of Woodstock. These fossils are in the highest beds just where they pass beneath the Upper Silurian slates. The fossils of this band, therefore, have a relation to the quartzites beneath, similar to that held by the Arenig fauna in the St. John basin, relative to the underlying Cambrian portion of the St. John group.

'In both areas the Ordivician fauna occupies only a narrow belt at the summit of the terrane, the great bulk of which is Cambrian. It would be impossible to show on a map of even moderate scale the Ordovician portion of the terrane in either of these areas; and, therefore, it seems to the writer desirable that the Ordovician coloration should be removed from this portion of the geological map and Cambrian substituted.

Eruptive rocks of southern Carleton Co.

'Two types of eruptives appear in this region; one consisting of agglomerates and ash-rocks along the syncline that runs east and west in the valley of Eel river, and which also show in Monument Settlement, near Dinnen's Mill. The other type is associated with granitoid grits and gray levigated ash-rocks. Rocks of this character were noted at a number of points between the quartzite slate series and the black slates, but inclnded in the former. These rocks are seen on the St. John river at Woodstock, and at Oak Mountain and Dinnen's Mill in Monument Settlement; as well as further south and east in Canterbury.

Granitoid grits.

'These granitoid grits are found on both sides of a lenticular area in which Silurian fossils have been found between Benton and Canterbury, and they are succeeded to the south by quartzites which appear to be on the reverse side of a basin of which the Woodstock Cambrian quartzites form the north side. Next these to the south are the granites which traverse the central part of York county.

Silurian fossils.

Silurian.—The discovery of Silurian fossils in the basin above referred to, by yourself and Mr. W. J. Wilson of the Survey staff, show that all the strata in this district cannot be Cambrian.

'Within the area enclosed or bordered by granitoid grits there are slate conglomerates which lie outside of the localities where the Silurian fossils are found. These may form the limiting beds of a basin of Silurian rocks bordered by the granitoid grits, slates and quartzites of the Cambrian. This view implies that the black slates (Bretonian) of the Cambrian have been removed by denudation on the south side of the Cambrian basin and are there covered by the Silurian.

Fossils.

'The fossils found in this basin are brachiopods of Silurian type and some obscure corals. The course of this basin of Silurian rocks is nearly parallel to that of the Cambrian, and its axis lies to the south of the axis of the Cambrian basin.

Syenite.

'*Intrusive Syenite.*—A band of intrusive syenite which runs nearly parallel to the western syncline of the Cambrian rocks has affected their condition in Benton and its vicinity, throwing them into close folds parallel to the direction of the syenitic ridge, and causing a very marked squeezing together of the black slates, so that the hydrosomes of the Dictyonemas are shortened in one direction and lengthened in the other. The rods of the hydrosomes that lie transverse to the line of pressure are nearly twice as far apart as those that are parallel to it, and the colonies of these animals might be thought to consist of two species, if it were not observed that the width of the bars is always governed by the direction in which the colony lies on the slab of slate.

Upper silurian graptolites near Fredericton.

'*The East Central Part of York County.*—Another belt of slates and quartzites which crosses York county and which has heretofore been thought to be of Cambrian or Ordovician age has yielded you graphites which it appears to me must belong to the genus *Monograptus*. This discovery of Silurian graptolites within a few miles of Fredericton has received further support from the finding of two species of *Monograptus* in shales several miles further to the north-west. This, coupled with the discovery many years ago of Silurian fossils on the Nashwaak, might be supposed to indicate that the whole of this belt of slates may be referred to the Silurian, as the strata are very uniform over large areas.

Silurian rocks.

'*General Comparisons.*—One should bear in mind that there are two important divisions in the Silurian terrane of southern New Brunswick. The older of these is to be correlated with the Clinton and Medina groups of the New York system. In most places it consists of black and dark grey slates and grey quartzites and flags. These are the 'dark argillites' of the Survey Report of 1875-76. To this division belong the slates and quartzites with graptolites described above.

Silurian of Rocky Brook.

'The distribution of these slates in York county appears to indicate that the overlying division may rest unconformably upon it, else we should find the upper division infolded with it. This may be the case at Rocky brook, on the Nashwaak, where fossils of the summit of the Silurian have been found. With the exception of this area on Rocky brook, the upper division of the Silurian has not been recognized in this area in the centre of York county.

Pale argillites.

'The pale argillites of the Survey Report of 1875, &c., form the upper part of the Silurian system in this region. They are found north and west of Woodstock, in Carleton county, and on the other hand are to be seen in a belt along the south side of the central Carboniferous area of Central New Brunswick. This division would include strata of Niagara and Upper Helderberg age. It is more calcareous than the Lower Devonian, and fossils are found in it in a number of localities, and then of such a kind that the Silurian age of the rock has usually been easily recognized.

'Compared with the Silurian series of Passamaquoddy bay at the Mascarene shore (see Report of 1874-75), the pale argillites would correlate with divisions 3, 4 and 5. Of these, division 3, according to

Dr. Ami, contains a Niagara fauna. The dark argillites would compare with divisions 1 and 2, and to this portion of the system, as above remarked, the graptolite beds of York county should belong.

'In conclusion, let me say that any light I may have been able to throw on the age of these rocks is due to your excellent judgment in taking me to such localities as would yield important data for correlation.

'I am, yours sincerely,

'G. F. MATTHEW.'

Previous opinions confirmed.

The above conclusions of Dr. Matthew, so far as they relate to the rocks of northern York and of Carleton county are in the main similar to those already reached by myself, and in part stated in previous reports. While, however, the general structure, within the region examined, may be regarded as fairly well ascertained, the details of distribution, owing partly to the disturbed and altered condition of the rocks and partly to their concealment by forest and drift, present many difficulties. It is proposed that these shall be made the subject of a special report now in course of preparation.

Silurian graptolites near Fredericton.

The discovery of Silurian fossils *(Monograptus)* in the quartzite-slate band south of the granite was made by me during the past summer on Murray's brook, seven miles west of Fredericton. Subsequently, in my company, Dr. Matthew found similar forms on the right bank of the St. John river, in Central Kingsclear, five or six miles distant from the locality first named. From the uniformity of the beds between these points and over all the area to the westward as far as the international boundary, we believe that all are of one system, and that the tract, coloured on existing maps as Cambro-Silurian, must be assigned to the Silurian system. The same will be true of much of the region east of the St. John river in the southern portion of the parishes of Queensbury and Bright; but, inasmuch as along the valley of the Keswick river they pass beneath the rocks of the Coal formation, of which the border here bends far to the north, we are unable as yet to connect them directly with the rocks of the Nashwaak valley. With the exception of the fossiliferous strata found on Rocky brook and referred to above, the rocks of this valley, as seen at Stanley, as well as those of Tay creek, McLean's brook, Ryan's brook, the Taxes and the S. W. Miramichi, are more highly altered and may be of greater age.

Work with Mr. H. S. Poole.

Another work assigned to me for the past summer was the revision, in connection with Mr. H. S. Poole, of the Carboniferous rocks of New

Brunswick, a subject in which public interest has recently been awakened, partly as the result of private enterprise, but mainly on account of the efforts of the New Brunswick government to promote the development of the coal fields at Grand lake, Queen's county.

Considering the nearly horizontal attitude of the coal rocks in the great central Carboniferous basin, and the fact that the observations of many years had failed to reveal the existence of other than small seams near the surface, the all-important question appeared to be the determination of what part of the entire Carboniferous system these surface rocks represent; that is to say, whether they are the equivalents of the Mill-stone Grit formation, as contended by some geologists, or of this formation with a portion of the middle or productive measures, as thought by others, or finally, whether they appertain to the Newer or Permo-Carboniferous period. While the first view would seem to preclude the possibility or at least probability of any considerable seams being found, the second and last would favour, though by no means establish, such conclusion.

Comparison with Carboniferous rocks of Nova Scotia valuable.

In attempting to arrive at any definite opinion upon this subject, it is evident that a comparison of the Carboniferous rocks of New Brunswick with those of Nova Scotia, where this system is so well represented and has been so thoroughly exploited, should be of the greatest possible value. With this object in view, a joint survey of the field was undertaken by Mr. Poole and myself, at the request of the Director, my knowledge of localities in New Brunswick enabling me to point out, without loss of time, such places as would be likely to afford valuable information, while Mr. Poole's long and intimate acquaintance with the coal districts of the sister province, made it possible for him to institute the desired comparisons. All parts of the coal field were visited by us together, but, as constituting the connecting link between the Carboniferous areas of the province, special attention was paid to the districts about Moncton, Sackville, Dorchester and the Albert county coast. The general results of the comparisons referred to are embodied in the Summary Report of Mr. Poole, accompanying this; while a more elaborate and joint report, reviewing the whole subject of the Carboniferous system in New Brunswick, will be submitted as soon as it is prepared. In the latter, all the facts bearing on the occurrence of coal in the province, as derived from the topography of the district, evidences of erosion, surface exposures, stratigraphy, mining operations and bore-holes, will be considered at length, and recommendations will be offered as to future practical work.

Proposed reports on the area.

ECONOMIC MINERALS.

Operations in the Grand Lake coal basin.

Coal.—The railroad connecting the coal mines at Grand Lake with Fredericton is in course of construction, and when completed next summer, is expected to lead to a much more vigorous working of the mines than has heretofore been attempted. The railway company is asked by the government of New Brunswick, in return for a subsidy, to supply a plant capable of producing 500 tons of coal a day, or 150,000 tons per year. It remains, however, to be seen, whether, under the conditions existing at Grand lake, such a production can actually be maintained. With a yield of 2,000 tons to the acre, 500 tons would involve the removal of coal from one-fourth of an acre per day, or from one acre every four days, which, with an average soil-capping of 12 feet, would mean a large amount of unprofitable work; while in the case of operations wholly beneath the surface, the necessity of the removal of sufficient rock to allow room to the workmen would again be a serious drawback. It cannot, however, be doubted that the output of these mines, especially with the present high price of coal, might be materially increased.

Work at Dunsinane coal mine.

More or less work has been done in the Dunsinane coal field during the past summer, but only of an exploratory character. No important developments have been made.

At Coal Branch, in Kent county, a shaft has been sunk in the vicinity of the coal seams previously reported there, and where operations were believed to indicate the existence of a three-foot seam of coal at a depth of 44 feet. The drill used, however, being a churn-drill, could not give very accurate results, and those obtained by shafting have not yet been reported.

Petroleum.

Petroleum.—Petroleum was discovered in Westmoreland county over thirty years ago, and its occurrence there may prove to be of importance. For the following statement of work done in searching for oil in this county I am indebted to Mr. Harold B. Goodrich, the geologist in charge for the owners, and it is given entirely on his authority. According to Mr. Goodrich: 'After a summer's field work in New Brunswick, well No. 1 was located at Upper Dover, Westmoreland county (on S. A. Steeve's farm) in September 1899. It was driven to a depth of 1,340 feet. The geologic column was:—

Boring No. 1. Upper Dover

	Feet.
Middle Carboniferous (sandstone, &c.)	110
Lower Carboniferous (conglomerate, marl, &c.)	200
Albert shale formation	720
Probably older rocks	310
	1,340

'The two upper formations were nearly flat, but, as usual, the underlying Albert shales were found to be intensely folded and possibly faulted, so that the measure of their actual thickness is by no means correctly given in the column. We struck much gas at various horizons and two sands that were well fitted to contain oil, but were dry. The hole was abandoned in May, 1900. This first boring was a test to determine the condition of the Albert shale-oil beds under a cover of the younger rocks.

Boring No. 2. St. Joseph's college Memramcook.

'In May, 1900, the rig was removed to St. Joseph's college and well No. 2 was put down to a depth of 1,040 feet. There was much gas, and at 365–370 feet an oil sand and flow of oil was struck. Several accidents made it impossible to take advantage of this oil and the well was sunk further. At 670 feet, salt water was found. The drilling was entirely in the Albert shale series, which for the last 200 feet was mainly close-grained sandstone with shale bands.

Boring No. 3.

'No. 3 was begun one mile north of the college on February 27, 1901. The drilling was through hard and soft layers of Albert shale. A poor record was kept, and it is possible that a slight flow of oil or gas may have escaped the drillers attention. No petroleum is shown by the record, although the shales were highly bituminous. At 555 feet the well was abandoned owing to quicksands. The last ten feet was in red sandy marl or conglomerate.

Boring No. 4, oil found.

'Well No. 4 was commenced in May, 1901, at a point 400 feet north of No. 2 at the college. The total depth was 408 feet. At 176 to 204 feet there were twenty-three feet of oil-bearing sandstone. This was not recognized at the time, so boring was continued. Later the hole was filled up to this depth; it was torpedoed and a pumping apparatus was placed. While it has not been pumped continuously to date, there has been a considerable product which shows no sign of decreasing. The oil is of excellent quality.

Boring No. 5.

'Well No. 5 was located, on August 5, 1901, 200 feet S.W. of No. 4. The geologic section is practically the same as the latter; bituminous calcareous shales, with small hard limestone beds. At 174–178 feet there was a sandstone with considerable gas. At 247–275 feet is an oil-bearing sand (the same thickness as that of No. 4). No attempt was made to pump this well, but instead it was plugged and now awaits further development in the field.

Boring No. 6.

'The last week in August, No. 6 was located 100 yards N. by. W. of No. 4. Up to date we have reached 226 feet and are still sinking. In that distance we have passed through three separate flows of gas.

Almost the entire section is bituminous black shale. The present indications for a producer are excellent.

'In well No. 7, which was located on September 11, about 200 yards north of No. 4, we are now down about 340 feet. The section was similar to that of No. 6. At about 190 feet we struck gas, which was later cased off. At 326 feet there was a flow of petroleum, probably from fissures in the shale. We decided to bore still further, hoping for an increase in the quantity of oil. However, as the well is in excellent condition we can at any time use the present supply.' Boring No. 7, oil found.

The above wells were visited by the writer on the 5th of July, at which time, with a 2½ inch pump, worked by steam, the yield was four barrels for a period of six hours, or at a rate of from eight to ten barrels per day. The oil was a heavy, dark-green lubricating oil, well adapted as a machinery oil, and estimated as having a value of about $7.50 per barrel. Its specific gravity at 60° Fahr. is 0·860, while that of the American crude oil varies from 0·79 to 0·88. No analysis has yet reached me, but it is thought by those in charge that it will probably yield at least 30 per cent of burning oil, 15 per cent of lubricating oil and 10 per cent of solid paraffine. Yield of oil.

Copper.—While in Westmoreland county, a visit was made to the works of the Intercolonial Copper Company near Dorchester. The conditions of the occurrence of ore at this point have been given in earlier reports. The ore is of low grade, not averaging over 3½ per cent of copper, but is widely disseminated through the mass of the rock, from which, it is thought, that by the employment of new and improved processes it can be profitably extracted. For this purpose a large and expensive plant has been introduced, but at the time of our visit it had not yet been brought into operation. It is proposed to crush the entire rock, consisting of grey conglomerate and sandstone, more or less mixed with coaly matter and containing the ore, mainly chalcocite, in veins and scattered nodules, and, after roasting and treatment with acids, to separate the copper by electrical action. As copper ores of a like character and with similar associations are known to occur elsewhere in the province, as on the Nepinquit river, near Bathurst, the results of the operations at Dorchester will be awaited with interest. Copper mines near Dorchester.

At Chester, in Albert county, an opening was being made in a very hard ash-like rock of Huronian age, through which was disseminated small strings of chalcocite, associated with more or less green malachite. It adds another to the many localities in this great pre-Cambrian belt in which copper ores have been observed, but is less promising Copper deposit at Chester, than those of Alma and Point Wolfe, further west. No well defined lode was exposed.

Borings in the nickel deposits near St. Stephen.

Nickel.—The Government drill has been in operation in connection with the nickel deposits near St. Stephen, but without satisfactory results as yet. The extreme hardness of the rock, a crystalline diorite with disseminated pyrrhotite, makes progress extremely slow and expensive, while no important increase in the percentage of nickel has yet been found to warrant the outlay.

Molybdenite has been reported from the vicinity of the S. W. Miramichi, and good specimens have been shown to me, but I have been unable as yet to obtain any particulars as to quantity.

THE COAL PROBLEM IN NEW BRUNSWICK.

Professor H. S. Poole, Dalhousie College, Halifax.

Coal in New Brunswick.

Rocks of the Carboniferous system cover a very large area in New Brunswick, although but little workable coal has yet been found among them. It was hoped that in the extensive region in the north-eastern part of the province, in which these rocks had not been exhaustively explored, better coal seams than any yet known in that district, or near Grand lake, might be discovered at the surface, or that by carefully working out the geological structure, some place might be pointed out where borings for coal might be made with a good prospect of success. Professor H. S. Poole of Dalhousie College, Halifax, was requested to undertake this work. He had previously made a study of the coal measures of Nova Scotia, including Cape Breton, while Inspector of Mines for that province, and also while actively engaged in the practical working of some of its collieries.

Investigations by Prof. Henry S. Poole.

He reports as follows :—'I considered the problem of discovering coal from a commercial standpoint, as though I were engaged by a corporation, prepared to explore and follow up any indications that held out even the least prospect of success towards the establishing of permanent coal-mining operations. Two months were spent in making a general reconnaissance of the Carboniferous system in New Brunswick and studying the relation of its strata to the rocks underlying the same system in Nova Scotia and to their assumed equivalent in that province, visiting many of the known exposures of coal seams, regardless of size, and keeping in mind my experience elsewhere of seams variable in thickness and coal measures hidden under formations of later deposition. In this inquiry I allowed myself to generalize more freely than would be justified if one were engaged in a detailed survey of the actual exposures, and as yet, in possession only of superficial information. The benefit of any doubt was given to the inquiry.

Area of Carboniferous rocks.

For convenience of description, the area occupied by the rocks of the Carboniferous may be divided into two districts by a line running through the older rocks of Indian mountain some six miles to the northward of Moncton, and paralleling the Intercolonial railway between St. John and Moncton. Such a line traverses Lower Carboniferous rocks, except between the mountain and the Straits of Northumberland, where newer measures overlap. North of the line the Carboniferous beds lie practically flat and unbroken. To the south, they are more inclined and disturbed, appearing on the confines of Nova Scotia as continuations of members of the Joggins section.

The people of New Brunswick are so keenly alive to the value of workable seams and the streams of the province have been so thoroughly traversed by lumbermen, that it may be accepted that no seam of workable thickness crops to the surface and has been overlooked. This being assumed, it follows that success from further search can be hoped for only where experience or theory may suggest examination being made under the superficial deposits or by boring into the more deeply seated strata.

Renewed interest in known coal seams.

Of the known coal seams, nothing specially new has to be reported. They have been described in late reports by Dr. Ells and Prof. Bailey. There has, however, been renewed interest in explorations at Dunsinane and Coal Branch, and a beginning has been made in the sinking of a slope at the former and a vertical shaft at the latter place.

Throughout the northern district, nothing was noted that indicated a possible presence of thick coal seams either near the surface or in depth—nothing to hold out hope that measures rich in bituminous deposits might be discovered by systematic search. The only discovery that seemed possible would be that of a thickening of the thin seams in those parts of the country that are as yet unexplored.

Coal pebbles.

At Indiantown, coal pebbles with water-worn fragments of fine shale appear in some sandstone beds and they have been apparently derived from an underlying seam not at present known. A somewhat similar occurrence of coal pebbles has been noted to the east of Dunsinane.

The southern part of the Carboniferous district, with its thick sections and its unconformities, possesses possibilities of finding workable coal on closer examination. It appears that certain beds on the New

Brunswick side of the Bay of Fundy are continuations of some of those in the Joggins section which have a definite relation to the coal-bearing series of Cumberland county, and they entered through Cape Maringuoin, Grindstone Island and Mary's Point to New Horton, where they curve rapidly and run down the coast at an increased angle of dip to Cape Enrage. With them would curve the overlying Joggins seams, outcropping under the waters of Shepody Bay.

To the north-eastward, the structure is not so clear. The Millstone grit series folds over, dips to the north-west and is unconformably covered by Permo-Carboniferous strata where the dip again reverses. So decided an unconformity suggests that the equivalents of the Joggins coal measures may possibly be repeated in that direction under newer formations extending to Northumberland Strait and up the coast.

Assistance.

During part of my time I had the benefit of Prof. Bailey's company, experience and local knowledge. I am also indebted for information and assistance to many persons interested in developing the resources of the province, chief among whom are Lieut.-Governor McLellan, Hon. A. T. Dunn, Mr. F. Black, Mr. P. S. Archibald, Mr. J. White, Mr. W. Ogden, Capt. Bacon and Mr. H. C. Read.

PRINCE EDWARD ISLAND.

Mr. Lawrence W. Watson.

Work by Mr. Lawrence W. Watson.

Acting upon the instructions contained in your letter of the 17th June last, I have, since receiving the same, prosecuted the work therein outlined at every possible opportunity. The conditions under which the work was undertaken naturally differed in a considerable degree from those governing the members of your permanent staff or those persons employed for a time upon investigations for your Department to the exclusion of all other work. This consideration, and the fact that much data for an exhaustive report upon several parts of the inquiry committed to me could not be procured without an expenditure (needless because not demanded by any existing urgency) which might be avoided, without detriment to the ultimate result desired, by waiting for and taking advantage of favourable opportunities for visiting distant localities without much attendant expense, make it imperative that the present report be a preliminary one, to be supplemented later by one in fuller detail.

In no particular of the investigations undertaken is the necessity of these considerations more emphasized than in the endeavour to solve the problems of our geological formations, for the solution of which, much patient search has to be made for fossils, by no means abundant in our strata. I have visited many localities and spent much time in collecting the fossils which have been forwarded to you. Much work must still be done before the question of the exact positions of our rocks in the geological scale can be satisfactorily settled. The geology of St. Peter's Island has not been studied as much as it deserved to be, owing to its difficulty of access. I hope, however, to be able later, to report upon this locality which is comparatively rich in organic remains.

Geological value of work.

Investigations so far made do not warrant any change in the opinion that coal areas may underlie the Post-Carboniferous rocks of certain districts at a depth not too great for mining. As the depth of the superincumbent strata may be less than anticipated, and as the coal measures with their wealth of coal may be nearer the surface than is generally supposed, and as the cost of boring is less than formerly, it seems desirable that in view of possible success, such operations should be undertaken in these districts.

Underlying coal areas possible.

No minerals of any importance have been found. I collected some nodules of copper ore on Governor's island, but did not find indications of any considerable deposit. I have not been able to find any evidence that gold occurs in this province to any greater extent than the reported discovery of 'colours' in the sand of the sea-shore.

No minerals found.

In the department of Surface Geology a few words may be said about recent deposits. Peat bogs, of small individual extent, but covering in the aggregate a considerable area, are found in many places, the quality of the deposits and their depth varying greatly. Some of them have been visited, but consideration of these will best be reserved until a comparative statement can be prepared showing their extent and the results of analysis of the peat. This subject suggests economic possibilities of too great importance to this province to be disposed of without fuller investigation than the time allowed for this inquiry and report permitted.

Peat bogs.

Beds of 'mussel mud' are frequent in our bays and inlets. Formed of accumulations of shells of oysters and mussels, decayed animal matter and alluvium, they constitute a valuable fertilizer, much used by our farmers. It is pleasing to record a late regulation, which prohibits digging the mud where it is covered by beds of living oysters. I shall take advantage of the approaching season of digging to submit samples of this product to you.

Sand dunes.

In view of the fact that our coast-line is very generally being worn away at a comparatively alarming rate, the formation of sand dunes on our northern and eastern coasts is interesting and important. While these are of comparatively slow formation, the whole contour of one of these sand-hills may be changed in one storm, and entrance into harbours may be shifted or occluded. I observe that the sand dunes upon which vegetation grows, change least, and that the sand is arrested by any such object as a fallen tree, and thereby protected from displacement by powerful winds. Most beneficial results would, therefore, follow if fences of spruce and similar trees were placed in parallel lines along the sand tracts.

I have devoted much time to the study of the flora and have collected some hundreds of plants. As soon as time permits, I will, if desired, give a complete list of all the species of our flora hitherto authentically identified.

Collections made.

Collections of mollusca, algæ, reptilia, batrachia and the smaller mammals have been made and forwarded to your Department. I visited and made collections from Indian shell heaps, finding therein ornaments or implements of stone and fragments from the manufacture of the last mentioned, all of which have been already forwarded.

The foregoing is an outline of the work done. It may be supplemented later by a report in more detail containing lists of fossils and of our fauna and flora, together with further notes upon the various subjects you suggested for study and investigation.

KINGS AND HANTS COUNTIES, NOVA SCOTIA.

Mr. Hugh Fletcher.

Work by Mr. H. Fletcher.

The winter of 1900-01 was spent by Mr. Fletcher in compiling plans and sections from surveys made in the field by himself and his assistants during the previous summer, as detailed in the Summary Report for 1900, pages 162 to 166.

Coal seams examined.

He left Ottawa on June 18, for Sydney, Cape Breton, to examine borings and explorations made among coal seams of the Millstone Grit, near Grand lake and Cochran lake. The Tracy seam near the Moseley pits south of Cochran lake, was proved to be six feet thick, but to have not more than three feet and a half of coal in one clean layer, three small partings breaking up the rest of the coal. The seam, where opened, some miles farther west, yielded three feet and a half of good coal.

On Grand Lake road at the bridge over South-west brook, a hole, bored in the hope of cutting a workable extension of the Mullins or Carroll seam, passed through 750 feet of gray sandstone with only a few thin layers of shale and coal. Subsequently a hole was bored to this seam at the outlet of Lynk lake, near the outcrops mentioned in the Summary Report for 1895, where it was found to be only three feet thick. In no case was more than one workable seam found.

Extension of the Mullins seam bored for.

The greater part of the season, however, was spent on the south side of Minas Basin, in the counties of Kings and Hants, in the district lying between the Avon river on the east and the Salmon-tail river, Gaspereau lake, and Coldbrook on the west, bounded on the north by the shore from Falmouth to Ira Woodworth bay, and extending south into the granite country at the head of the west branch of Avon river. Mr. M. H. McLeod was again Mr. Fletcher's assistant, and he had also with him Messrs. A. T. McKinnon and Wm. L. Lodge. He is greatly indebted to Professors A. E. Coldwell and Ernest Haycock, of Wolfville, to Professor Kennedy of Windsor and many others for assistance.

Principal field of investigations.

Though this district is more noted for its early history, the picturesque beauty of its shores, waterfalls, lakes and woods, the richness of its meadows, and productiveness of its farms and orchards than for its mines, yet rock-formations of great interest attract tourists and students to the country every year, to study its geology, and carry away specimens of the amethyst, agate, jasper, chalcedony, zeolites, magnetite, copper and other curious crystals and aggregations from its traps, the beautiful selenite and fibrous gypsum from its Triassic marls, and ripple-marks, rain-prints, fish-remains and other fossils from its more indurated sediments.

District historically interesting.

Remains of the villages of the Micmac Indians, their landing-places, trails, and burying-grounds,are still traceable at Starrs Point, Canard, Gaspereau and other places. Heaps of shells and bones of various animals attest the former abundance of game and fish. They are associated with implements and arrow-heads of a primitive civilization, chipped out of stone obtained from Blomidon or fashioned from pieces of native copper from Cape d'Or.

Relics of Indian inhabitants.

The ancestors of the Acadians, who displaced the Micmacs, to be dispossessed in turn by the British, came from a country of marshes on the west coast of France, where the sea was kept out by artificial means. They found around the Bay of Fundy, in Nova Scotia and New Brunswick, similar marshes underlaid by finely pulverized, friable red mud, brought in by the tides, into which the roots push themselves for several feet; and turning to account their skill and experience, they

The Acadians.

built many miles of dyke, at first enclosing small areas alongside the upland; next, by concerted, skilful effort, building across the rivers from point to point, with a sluice or *aboiteau* in the channels to let out the fresh water and keep the salt water from flooding the marshes and killing the vegetation. By this means they reclaimed and brought under cultivation thousands of acres of excellent meadow-land, which has retained its extraordinary fertility for one hundred and fifty years, and still produces grain, vegetables and fruit, yielding two to three tons of timothy to the acre when well drained, turned over and seeded down once in every five or ten years, and is sometimes so valuable as to be rated at $400 per acre.

Marsh lands reclaimed.

The home of Evangeline.

One of the largest of these marsh lands is Grand Pré, in Kings county, celebrated in verse as the home of Longfellow's Evangeline, and situated between the beautiful valleys of the Gaspereau and Cornwallis rivers, up which the phenomenal tides of the Bay of Fundy run for several miles to form, at high water, inlets navigable for small craft. Near it are the willows and apple-trees of the early French farmers, a well and the ruins of their church and houses.

Other dyke-protected meadows occur at the mouths of the Avon, Canard, Habitant and Pereau rivers, of historic interest in the struggle for supremacy in the New World between the English and French, during the seventeenth and eighteenth centuries. They are bordered by sloping fields and undulating uplands, while away to the northward Blomidon rises to a height of 500 feet, crowned with evergreens and hardwood, opposing to the turbulent tides a perpendicular wall of basaltic trap, jutting out past the fringe of bright red sandstone that forms the cliffs to Pereau and Kingsport. Cape Blomidon is the eastern buttress of the north mountain range, which, extending thence to Brier Island, shuts out the fog of the Bay of Fundy from the Annapolis valley. Another elevation of great scenic interest in this vicinity is the 'Look Off,' three miles from Canning, from which an extensive view is presented of the surrounding country, with fine orchards laden with apples, plums, pears, cherries and small fruits, gardens and grazing lands for cattle and sheep; and deep valleys, lakes and woods, dimly seen to the southward, full of trout and salmon, moose, bears, partridges and other game. Many such fine views and imposing and attractive pieces of scenery are easily accessible from the railway. Among these are the valleys of the Gaspereau and Coldbrook, the Deep Hollow, Whiterock, Black River falls, Moores falls, the beaches and sea cliffs, particularly between Kingsport and Blomidon.

Cape Blomidon.

Places attractive for scenic beauty.

The dyke lands have been described by many writers.*

Geology of Kings county.

Kings county affords a great variety of geological formations. Those of sedimentary origin belong to the following periods: Pleistocene, Triassic, Carboniferous, Devonian (Horton), Silurian (perhaps including Cambro-Silurian or Upper Cambrian), Lower Cambrian (upper gold-bearing series). Igneous or Plutonic rocks are also present in hill-masses and dykes. Following the Triassic came a great effusion of trap. All the rocks to the top of the Silurian are affected by an intrusion of the gray granite that forms so important a feature on the Atlantic coast; and are also cut by dykes of gray diorite. These intrusions appear, however, to differ in age and material from that which has formed the Cobequid hills and altered the strata of Riversdale and Harrington river.

Notwithstanding all that has been written† in general descriptions of these formations, much still remains to be done to define on a map their precise boundaries and relations.

Drift material.

Drift material from the North mountain is found as far south as Etna (Greenfield) and other points on the South mountain. Pebbles and boulders from the Cobequid hills also abound in the boulder-clay of all the sea cliffs, valleys and beaches. Professor Coldwell has described south-easterly glacial striæ on rocks of the ridge immediately south of Wolfville; an old beach-formation parallel to the present water frontage at the same place; and trunks, stumps and roots of trees *in situ*, about thirty feet below high-water mark on the northern side of Long island, representing, he argues, a subsidence of the land of forty to fifty feet. An interesting deposit of shell-marl, used as a fertilizer, has been dug from a bog on the land of Mr. William Wallace at Canaan. Bog iron and manganese have been worked to a small extent south of Coldbrook station, at Canaan and other localities.

Bog iron and manganese.

Description of Triassic belt.

The southern limit of the Triassic runs westward from Avonport and follows a short distance south of the Cornwallis river. The belt, which has an average width of six miles and a half, is bounded on the north by the North mountain, the uppermost beds being those cut by the trap. It contains, near Kingsport, friable sandstone, for the most part brick or Indian-red, with great irregular layers or patches of conglomerate; overlaid, towards Pereau, by finer marly beds, which extend to Blomidon and include layers of selenite, nine inches and downward, in the upper portion. A narrow outlier is found in the large brook above Kentville, separated from the main basin. Sections of these rocks have been measured wherever accessible. Their total thickness is not great. They are spread over this large tract in almost horizontal layers, and it has been suggested that underlying formations might be reached by boreholes.

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*Herbin's 'Marshlands' and 'Grand Pré'; Haliburton's 'Sam Slick' and 'History of Nova Scotia'; Longfellow's 'Evangeline'; Macleod's 'Notary of Grand Pré'; Theodore Rand's Poems; Gesner's 'Geology and Industrial Resources of Nova Scotia'; Dawson's 'Acadian Geology'; and others.

†Report by Jackson and Alger; Gesner's 'Geology of Nova Scotia' and 'Industrial Resources'; Dawson's 'Acadian Geology'; Papers by Professors Coldwell and Haycock and by Dr. Honeyman in the 'Transactions of the Nova Scotian Institute of Science'; and others.

Carboniferous limestone.

From a point half a mile above the West Branch, the Avon river flows through a basin of red and gray marls, flags and sandstones, gypsum and limestone of the Carboniferous limestone formation. In the neighbourhood of the plaster and limestone quarries of St. Croix, Windsor, Falmouth, Mount Dennison and Hantsport this basin is of great extent; but it enters Kings county only in a narrow zone along the shore from Hantsport to Blue Beach.

Horton series.

A somewhat irregular belt of more metamorphosed rocks is met with in the West Branch of Avon river, the Mill Branch, Halfway and Gaspereau rivers. These, as they occur at Horton Bluff, have been called the Horton series.* Sections have been made there and on the Curry and other brooks flowing into Gaspereau river, to define their thickness, which is probably not less than on the north side of Minas Basin. The base is well defined at Gaspereau, Halfway river and other places; from it the 'Wickwire sandstone' is largely quarried for foundations of buildings; and it yields also the quarry sandstone of Halfway river.

Controversy as to true position of Horton series.

A brief reference may here be made to a controversy that has arisen among palæophytologists concerning the true position of this series.† Some of them, while correlating the Horton with the rocks of Riversdale and Harrington river, in Colchester county, have classified it as above the Devonian of New Brunswick; others regarding the Riversdale and the Devonian of New Brunswick as identical, would place the Horton beneath them. In the region now under examination, the Horton rests upon no rocks younger than Silurian, and comes from beneath the Carboniferous limestone, 'the old Lower Carboniferous, or Keokuk-St. Louis,' according to Schuchert, and is clearly, therefore, neither Upper Carboniferous nor Millstone Grit. 'Surely,' an eminent palæobotanist remarks, 'the coefficient of error should not be so great as to permit an entire geological period to intervene between its palæontologically theoretical position and its actual place.'

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* Acadian Geology, pages 252—257.

†'A Backward Step in Palæobotany,' by Dr. G. F. Matthew, in Trans. Roy. Soc. Can. for 1901; Can. Record of Sc., Jan. and July, 1901; Ottawa Naturalist, May and July, 1901.

The rocks next underlying contain, between Canaan and Gaspereau lake, Silurian marine fossils.* West of New Minas, the fossil, *Dictyonema Websteri*, is obtained from a series apparently distinct, resembling the so-called Cambro-Silurian of Antigonish and Pictou counties, but referred by Dawson to the Silurian, by Honeyman to the Lower Silurian, and by Coldwell to the Cambrian. The stratigraphical relations have not yet been thoroughly worked out. From the former are quarried the impure limestones of Gaspereau lake and Canaan; from the latter, the flinty, quartzose flags of Highbury.

Marine fossils found in underlying series.

Graphitic slates of the age of the Lower Cambrian or Upper Gold-bearing series, sometimes so black as to be worked for graphite, are largely developed in the Halfway, Black and Gaspereau rivers. They are cut by small veins of quartz, some of which have been exploited but do not seem to be persistent or to carry gold. Just below a bridge about three miles above the mouth of Black river, an east-and-west anticline brings to the surface beds of whin; but it is not known that gold-bearing veins have been discovered along its axis.

Graphitic slates of Lower Cambrian age.

This series, as well as the preceding, is everywhere intersected by dykes of light-gray dioritic rock and cut off to the southward by a great mass of granite, which stretches nearly to the Atlantic, a blackish granular diorite generally occupying a narrow zone at the contact. The diorites and the granite are all, however, older than the Horton rocks, the latter containing fragments of both. The granite is usually gray, but in Black and Little rivers it is in part red. Both varieties make durable ornamental and building stones. Where Triassic rocks are broken through by the trap of the North mountain the alteration of their soft sediments does not extend to many feet from the contact. Vuggs, both in the latter and in the trap, are filled with crystalline aggregations varying in size from mere druses to several inches in diameter, and veins and plates contain many other minerals already described as characteristic of the traps of the Bay of Fundy at Cape Blomidon and many of the small coves from Scotts bay westward—the amethyst and black quartz, agate and jasper being especially prized by collectors. A list of the varieties to be obtained at different points is given in Dr. Hoffmann's 'Annotated List of Canadian Minerals.'†

Rock series cut by diorite dykes.

Characteristic minerals.

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* Acadian Geology, pages 562 to 573, 594.

†Cf. also 'Acadian Geology'; Gesner's 'Geol. of N. S.'; Jackson and Alger; Herbin's 'Grand Pré'.

Columnar, granular or crystalline, basaltic trap occupies a narrow chain along the contact with the Trias from near the 'Look Off' to Cape Blomidon, thence on the outer shore to Cape Split. The shores from Scott's bay westward to Baxter harbour and the greater part of the trap area inland are, on the contrary, occupied by sheets of amygdaloid, dipping north-westward at a very low angle.

Veins of magnetite are found at Blomidon, as at Gerrish mountain and other places, of less than workable size. Native copper and malachite are also present, but apparently in much less quantity than at Cape d'Or, in Cumberland county, where the Colonial Copper company is spending large sums of money in search of a paying deposit.

Borings near Leamington.

Fifty-six hand-drill borings, ranging in depth from 10 to 82 feet, have been made near Leamington, in Cumberland county, to trace the course of the coal seams overlying the large beds worked in the Springhill coal field, and the relation of these latter to small seams of the Upper Maccan river. These explorations were not undertaken, as has been already stated, for the discovery of workable coal seams at the surface, the outcrop of those of the Springhill mines having turned to the eastward and become concealed among faults at the bottom of the basin near Rodney; but to determine the lines along which the lower levels in the working of these seams must pass by the outcrops of small seams overlying them at stated distances. It is also desirable to ascertain whether the conglomerate upon the slope of the Cobequid hills south of Leamington and westward towards Apple river, instead of being Lower Carboniferous, may not rather represent higher measures, just as the 1,500 feet belt near the Chignecto and Styles mines is, according to Barlow and McOuat, a local replacement of the fine sediments that on the Joggins section immediately underlie or include some of the coal seams.

Assistance given.

For kind assistance in this work, Mr. Fletcher has again to thank Mr. J. R. Cowans, of the Cumberland Railway and Coal Company, the gentlemen mentioned on page 162 of last year's Summary Report and Mr. George C. Harrison, C.E., of Southampton.

NOVA SCOTIA GOLD FIELDS.

Mr. E. R. Faribault.

Office work by Mr. E. R. Faribault.

Mr. E. R. Faribault returned to Ottawa on August 26, 1900, from the Paris International Exhibition, where he had been sent to superintend the installation of the Canadian mineral exhibit; and after thre weeks field-work in the gold districts of eastern Nova Scotia, he reached Ottawa again on September 28 to resume his office work, on which he reports as follows:—

'The last three months of 1900 were spent in the office preparing a report on the collection of Canadian minerals sent to the Paris Exhibition* and in attending to correspondence and other duties in connection with the exhibit. I also prepared a plan to be used for the installation of that mineral exhibit in the space allotted to it at the Glasgow International Exhibition of 1901.

'The winter months of 1901 were devoted to the compilation of the large scale plans of the gold-mining districts of Waverley and Tangier in the county of Halifax, both of which were handed in for publication before leaving for the field. Some progress was made also in the compilation of the surveys made several years ago for the Lawrencetown and Preston map-sheets, lying immediately east of Halifax Harbour, and in this work I was assisted from May 1 by Mr. Owen O'Sullivan.'

Field work.

On the field-work accomplished in Nova Scotia during the past season, Mr. Faribault reports as follows:—

In accordance with your instructions, I left Ottawa on June 15 for Nova Scotia, to resume the surveys interrupted last year, in connection with the mapping and study of the structural geology of the gold-bearing rocks of that province.

Mr. Owen O'Sullivan also left for Nova Scotia on June 15, and from that date until his return to Ottawa on October 4 he was engaged with the exception of three weeks, occupied in surveying with Mr. C. O. Senécal, in continuing, under my supervision, the much delayed compilation of the topographical surveys of the region lying immediately east of Halifax Harbour and the line of the Intercolonial railway.

Assistants.

I was again ably assisted in the field, during the whole season, by Messrs. Archibald Cameron and Jas. McG. Cruickshank, who have been my assistants for sixteen and fourteen summers, respectively. They joined me at Halifax on June 18, and, after a few days spent revising surveys to the east and west of Halifax, they were engaged surveying the region passed over in 1896 and covered by the St. Margaret's Bay sheet, No. 71 and the Aspotogan sheet, No. 70. This region covers 240 square miles of land, includes the numerous lakes and streams flowing southward into St. Margaret's bay, and the East river of Chester, flowing into Chester basin, and it extends inland to the north and west as far as the old Annapolis road and the Windsor-Chester road. The shore roads were surveyed with the odometer, and several of the lumbering roads of the interior were chained to be used as tie-lines; while the streams, lakes and other traverses were measured by pacing and the prismatic compass.'

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* Summary Report Geol. Surv. Can., 1900, pp. 16 to 37.

With the exception of a few small outliers of Carboniferous limestone along the coast, the whole of the district surveyed is underlaid by granite, is very rough, with rugged rocky hills or huge boulders of granite strewn over the surface, and is of but little economical importance. The country is mostly barren along the coast, but well wooded with good timber some distance in the interior. It is unfit for agriculture and uninhabited, except along the sea-shore, where a prosperous scattered population is engaged in fishing and lumbering.

Messrs. Cameron and Cruickshank were engaged in the field until the 28th of October, when they began the plotting of their surveys.

Acknowledgments.

In the performance of my field-work, I have received much information and assistance from miners and other persons, and I wish to thank especially the Hon. C. E. Church, ex-Commissioner of Mines; Hon. A. Drysdale, Commissioner of Mines; Dr. Edwin Gilpin, Inspector of Mines; Hon. S. H. Holmes, and Messrs. Roderick McColl, D. Weatherbe, F. H. Mason, N. W. Keddy, Geo. E. Francklyn, T. N. Baker, J. H. Austen, and Sidney Y. Bauld, of Halifax; A. F. Church and J. B. Morrell, Bedford; Geo. W. Stuart, Truro; A. A. Hayward, Waverley; G. J. Partington, Isaacs Harbour; John H. Anderson and Mark Anthony, Musquodoboit Harbour; John J. Withrow, South Uniacke; Capt. C. D. Lordly, Alex. M. Church and Principal Lawson, Chester; John A. Wheeler, Irving Croft, D. C. Butterfield, Amos A. Hiseler, H. B. Bigney, Charles Mills, D. M. Fraser, and John Croft, Jr., Chester Basin.

Nature of work.

My own work in the field was confined principally to a closer study of the geological structure of the gold-mining districts of Montague and Lake Catcha, in the county of Halifax, surveyed in 1898, and briefly reported on in the Summary Report for that year, and the gold-mining districts of South Uniacke, situated partly in Halifax and partly in Hants county, surveyed in 1899, and also reported on in the Summary Report for that year. The structure of the anticlinal folds, the location of the auriferous quartz veins and the numerous faults affecting them were carefully made out, and the results added to the plans of these districts previously plotted on the scale of 250 feet to one inch. These plans are ready for publication, and that of Montague is now in the hands of the engraver.

A special detailed survey was also made of the gold district of Gold river, in the county of Lunenburg, and a plan plotted on the scale of 250 feet to one inch has been completed.

A revision was also made of the geological structure of the region lying to the north of Chester basin, between the East river of Chester, Gold river, and Chester Grant, surveyed in 1895, for the general mapping of the country, on the scale of one mile to an inch.

Some preliminary notes on the structure of the Gold River gold district will no doubt be welcomed by those interested in it.

Gold River gold district.

Gold River Gold-mining District.—This district is situated on the Gold river, in the county of Lunenburg, one mile above the bridge spanning the stream on the shore-road, where it discharges into Chester basin. It is five miles north of the town of Chester, twelve miles east of Mahone bay, a station on the Central railway, and fifty miles west of Halifax, by the shore road.

First discovery of gold.

There is a tradition that gold was originally found on the river by early French settlers, and hence its name. Another authority asserts that the name was originally 'Gould river'. The first discovery of gold of which we have positive information was made by Messrs. Daniel Dimock and David Whitford, on June 20, 1861. Mr. Henry Poole visited Gold river in 1861, and in his report to the Government said: "One quartz vein was fifteen inches wide, and had thick beds of quartzite rock above it, and several feet of thin laminated slates below, and the vein bore N. 60° W. and dipped 38° north." This description agrees with a quartz vein opened on the north-east bank of the river and shown to me as the first vein opened in the district.

Area of the district.

The mining operations have all, to this date, been prosecuted on the north-eastern side of the river, but important surface developments have also been made on the south-western side. In the district, gold-bearing veins have been discovered over an area 7,000 feet long and 4,000 feet wide. A detailed survey has been made of this area, and a plan plotted on the scale of 250 feet to one inch.

Geological structure.

Great difficulty was experienced in working out the geological structure of the district. No mining operations were being carried out when the survey was made and most of the old workings were full of water and inaccessible. The surface is heavily covered with glacial drift or decomposed rock and natural rock-exposures are very scarce. Were it not for the good sections available along the deep valley of the Gold river, and the informations gathered from the miners who have worked from time to time in the several mines, it would have been impossible to make out the structure of the measures.

Interbedded veins.

All the auriferous quartz veins discovered in the district belong to the interbedded class of fissure veins. They follow the planes of sedimentation of belts of slates interstratified between heavy beds of quartzites and they occur along the truncated dome of a huge anticlinal fold. The horizon of the strata brought up by this upheaval is estimated to be 6,600 feet below the base of the group of slates which form the upper division of the Acadian gold-bearing rocks, giving a total erosion of some 17,000 feet of known sedimentary rocks.

Horizon.

Anticlinal fold.

The general course of the anticline is north-east and south-west. At the western limit of the district, a six-inch lead, opened in a slate belt by Mr. N. W. Keddy, on area 1076, block 1, curves westerly around the crown of the anticline and pitches 37° west. The anticline is well exposed on Gold river at the Hemlock fall, where it pitches 15° south-westerly. At the eastern extremity of the district, on area 314, block 3, a five-inch lead discovered by Mr. Charles Mills in a wide slate belt just north of the Gammon group of leads, has been found to curve in a south-easterly direction around the crest of the anticline and dip 30° east.

Dome.

On the south side of the anticline the strata curve abruptly and dip southerly at high angles, increasing rapidly and reaching 85° at a distance of 2,000 feet to the south of the anticline. On the north limb the strata dip at much lower angles, and vary from 35° near the axis to 45° at a distance of 1,700 feet northward from it. The axis-plane of the fold dips thus to the north at an angle of 65°, and the upheaval has the form of a much elongated, elliptical dome whose centre is not far east of the bridge spanning the East Branch.

Veins on the south limb of anticline.

All the most important veins operated in the district are situated on the south limb of the anticline. The tilted-up strata of the south limb have necessarily been subjected to more shearing and fissuring in the process of the upheaval than the less disturbed ones of the north limb, and as a result they were more favourable to the formation of large auriferous quartz veins. So far, 32 leads have been discovered within a breadth of 2,300 feet of strata on the south side of the anticline, and of these 17 have been developed or worked to some extent. The present surface developments show that the veins are very persistent along their course from one end of the district to the other, and that they must also extend to very great depths.

Gammon group of saddle-reefs.

The district has not yet been prospected sufficiently to determine with any certainty the zones of special enrichment. The Gammon group of leads, opened immediately south of the anticline, at the east end of the district, is very promising as a low grade ore deposit.

Within a distance of 170 feet the group shows seven large quartz veins, dipping vertically, giving a total thickness of 70 feet of crushing material, and holding several bands of well mineralized ore. It is probable that this extensive development of quartz in the leads is confined to a relatively small portion of the crown immediately south of the anticline. The size of the veins will probably be found to diminish in depth, but, if the developments are carried in the direction of the axis-plane of the fold, which dips 65° north, a succession of large superposed veins will probably be discovered going to great depths. More development work should be done towards the west along this part of the anticline.

Minor fold.

An important crumple of the strata has been observed in a shaft sunk by Mr. T. N. Baker 500 feet south of the Gammon leads, on the intersection of the Baker fissure vein, running north-west and south-east, with the Vermilion lead, which follows the stratification. The foot-wall of the Vermilion lead is here crumpled into a small anticlinal, which runs N. 76° E., dips 31° E., and is followed 40 feet north by a small synclinal fold, beyond which the rocks assume their general course towards the north-east. The streak of rich ore found here is undoubtedly caused by this disturbance, and it is probable that similar enrichments will be found on the leads affected by this disturbance to the north and south of the Vermilion lead. Very rich drift has been found along a depression to the south-east, and it probably comes from the intersection of the Captain and the Picayune leads with either this crumpling or the Baker fissure vein.

Leads worked on the south dip.

The leads which have been worked on the south side of the anticline, are met with in the following order from north to south:—The Jumbo lead, worked to a depth of 80 feet; the Vermilion lead, 40 feet; the Captain lead, worked by several shafts at the Victor mine to depths of 200 feet, and at the Lincoln mine to depths of 119 and 250 feet; the Picayune, 200 and 211 feet; the Mill lead, 100 feet; the Fox lead, 70 feet; the Brisco lead, 40 feet; the Hiseler, 50 feet; the Croft Hill lead, 40 feet, and the Iron lead, 40 feet.

North Star lead.

As far as can be ascertained from the present developments, the leads which are most promising on the south dip are the Gammon, Jumbo, Vermilion, Captain, Picayune, Mill and Fox leads. The only lead worked to any extent on the north dip is the North Star lead, situated at a distance of 1,500 feet to the north of the anticline. A rich streak or roll, dipping west at a low angle, has been worked 600 feet in length and 100 feet in depth on this lead. The intervening section between the North Star lead and the anticline has not yet been much prospected. It is probable, however, that the ground immediately north of the Gammon leads and the anticline contains some valuable leads.

North-west bulge.

On the north-west side of the anticlinal fold the strata curve gently in a south-westerly direction towards the main anticline and form a broad bulge favourable to the formation of quartz veins. The rock section exposed along the Gold river, from Innes and Big Cumberland pools to the head of Mosher's fall, presents some eighteen interbedded veins situated on this bulge. Some have been tested and found auriferous, but none have been prospected to any extent.

Touquoy gold drift.

It is said that the richest drift discovered in the district was found on the old Touquoy property, at the south-west end of the district. Much prospecting has been done for many years back by Mr. Damas Touquoy and others to find the lead, but the surface is covered with glacial drift to a depth of twenty to twenty-five feet and the float of gold quartz is only found at the top of the drift and has possibly come a long distance. It is very probable, however, that the lead will be found on the above described bulge and possibly at no great distance from the anticline. More prospecting should be done along the anticline, between the Keddy lead and the Croucher lead, and beyond it as far as the Hemlock fall on the river.

Faults.

The structure of the anticlinal fold has been subjected to much disturbance since the folding and the deposition of the interbedded quartz veins. Unfortunately, the rock exposures are too few and the developments accomplished are as yet too limited to determine with any certainty the many faults affecting the district. Several of them run transversely through the anticlinal fold. A left-hand fault has been observed to give a displacement of seventy-five feet on the North Star lead, and running a little east of south along the west side of a swamp, it crosses the river at Big Cumberland pool and passes west of the Hemlock fall, where the anticline appears to have been shoved 200 or 300 feet, to the north of the Croucher lead. An important left-hand fault appears to have displaced the rocks along the Eastern branch, but its direction could not be ascertained. A left-hand fault, giving a shove of some twenty feet on the Croft Hill leads, runs up the river, passes east of the Jumbo crusher and eighty feet east of the eighty-foot shaft on the Jumbo lead. A few small faults have also been encountered in the workings of the Captain lead at the east end of the district. There is also probably a left-hand fault of 100 feet or more west of Baker's workings on the North Star lead, and possibly also to the east of them.

Several falls, cascades and rapids are met with along the course of Gold river through the district, and a few of these have already been utilized, in a small way, as water-power for the mines. An excellent water-power could be established at Little or Big Cumberland pool, where 75 or 100 feet of a head could be had with little cost from the Mosher's falls. With such a power in the middle of the district, there is not the least doubt that many of the large belts of low-grade ore, overlooked to the present day, could be worked at a good profit, and make the district one of the best producers in the province.

Excellent water-power.

CAMBRIAN ROCKS AND FOSSILS OF CAPE BRETON.

Dr. George F. Matthew.

During the past season I was engaged in June with Dr. Bailey in examining the slate and quartzite rocks of the western part of York county and the southern part of Carleton county, New Brunswick. Subsequently I visited, with Dr. Bailey, exposures of these rocks on the western border of the Carboniferous area in York county. The results of these examinations are given in Dr. Bailey's Summary report.

Work by Dr. Matthew in Cape Breton.

For the greater part of the month of July I was working on the Cambrian rocks in Cape Breton, examining some districts not previously visited and perfecting the work in other parts of the field. The general results of my work so far as they relate to the geological structure are embodied in the comparative table submitted herewith. From this table it will be seen that almost every Cambrian fauna of English rocks of this age occurs in the Maritime provinces of Canada. In other words the Cambrian history is complete, without breaks here as in Great Britain. The table also shows the position in the Cambrian formation of certain iron ores and slate deposits, and where mineral wealth of this kind may be looked for with the best prospect of success. The upper ferriferous horizon is in that part of the formation in which the hematite beds of Bell Island, Newfoundland, are contained. The lower iron-bearing band is in the middle of the red rocks of the basal part of the Cambrian.

Promising slate rock.

The most promising of the slate rocks of the Cape Breton Cambrian for economic purposes are found at the top of the basal part of the formation in the Mira river valley. They are of the same age as the argillites or clay slates that are quarried at Trinity Bay in Newfoundland. Their value will depend upon the ease of cleavage and accessibility to a market.

LOWER PORTION OF THE PALÆOZOIC ROCKS

English Equivalent.	Llandeilo.	Arrenig.	Tremadoc.	Dolgelly.	Ffestiniog and Maenterog.
Leading Genera of the Several Groups.	c. Harpes, *Trinucleus*, in N. W. New Brunswick.	d. Cyclognathus Parabolinella, *Tetragraptus*, Didymograptus, in S. New Brunswick.	c² *Asaphellus*, Parabollinella, Triarthrus, Bellerophon.	c. *Dictyonema*, Monobolina, Schizambon, Acrotreta. b. *Peltura*, Sphærophthalmus, Leptoplastus, Ctenopyge. a. *Parabolina*, Agnostus, Anomocare, Orthis, in S. New Brunswick.	c. Agnostus, Lingulella. (Place of Olenus.)
Maritime Provinces	3. Bretonian Division.				2. Johannian.
European Writers.	Ordovician.		Primordeal Cambrian.		
	Lower Silurian.			True or Eo-Cambrian.	
Groups, and kinds of Rocks in Cape Breton.	3. Dark gray, and black carbonaceous shales often changed to slates; a few thin seams and lenses of dark limestone and some thin flags.				2. Micaceous gray slates, flagstones and quartzites. Iron-bearing in Mira Valley, Cape Breton.

IN THE MARITIME PROVINCES OF CANADA.

1. Dark gray slates or shales with calcareous lenses. Gray sandstones. Interraned conglomerates at and near the base.	True or Eo-Cambrian.		1. Acadian.	*b.*	*Paradoxides*, Beyrichia, Lingulepis. Obolus, Lingulella.	Menevian.
				d c.	*Paradoxides*, Solenopleura, Ptychoparia, Microdiscus.	
				c.	*Paradoxides*, Conocoryphe, Liostracus, Agnostus.	Solva.
				a-b.	*Protolenus*, Ellipsocephalus, Beyrichona, Trematobolus, in S. New Brunswick.	
3. Fine greenish gray argillites, some reddish gray. Horizon of roofing slates in C. Breton and Newfoundland.	Sparagmite Formation, Norway.	Basal Cambrian. (Mihi.)	Etcheminian.	3. Upper.	Ptychoparia ? Ostracoda, 4 genera. *Acrotreta*, Lingulella, Obolus. Acrothyra, Hyolithes.	Caerfai.
2. Red sandstone and red and gray argillite. Lower iron-bearing horizon of Cape Breton Cambrian.				2 and 1, Lower.	*Holasaphus*, Paradoxidoid trilobite, Ostracoda, Billingsella, Lingulella, Acrothyra, Obolus, Hyolithes.	
1. Gray shale or slate, with some quartzite and conglomerate, the latter especially at the base.					Lingulella, Leptobolus, Obolus. Acrothyra, Acrotreta, Hyolithes.	
Co. Dolerites, breccias and amygdaloidal ash rocks. Some gray shales about thé middle.			Cold-brookian.		Lingulella, 2 Ostracoda. Acrothyra, Acrotreta.	Pebidian ?

Having but a short time at my disposal in Cape Breton this year, I devoted it to extending the examination in the district already explored, and to study some doubtful points which I had not been able to settle satisfactorily when previously in the island.

In the valley of the Mira river, by the discovery of the Paradoxides fauna at several points, I was better assured of the distribution of the middle members of the Cambrian system, and by exploration on St. Andrews channel, I was able to satisfy myself that strata, formerly thought to be more recent than the Cambrian, were of that age. Details in reference to these matters will appear in my fullest report.

General result of the exploration.

I may now add some statements in regard to the general result of the exploration—first, in its bearing on a scientific knowledge of the Cambrian of the Atlantic provinces, and—second, in regard to a few facts bearing on economic points. The writer may premise that previous to his first visit to the island, two Cambrian faunas had been discovered there; the first, before the work of the Geological Survey of Canada was extended to the island. This was made known by the late Dr. D. Honeyman, and was the fauna of Peltura and Sphœrophthalmus fossils which were found on McNeil brook, of the Mira river, and sent to the great exhibition in London, where they were determined by the late J. W. Salter. The second discovery was made by Mr. Hugh Fletcher, during exploration for the Canadian Geological Survey, in the valley of McLeod brook, near Barasois. These fossils were examples of Dictyonema, and were determined as being of the species *D. socialis*, Salter (= *D. flabelliforme*, Eichwald), by Prof. Chas. Lapworth.

Recognized European faunas.

Other fossils were collected in various parts of the Cambrian field by Mr. Fletcher, but they did not result in determining any known Cambrian horizon. Thus, of the five European faunas of the Cambrian-Paradoxides, Olenus, Peltura, Dictyonema, and Asaphellus, only the third and fourth had been recognized. And of the faunas older than Paradoxides, the varied fauna of the Protolemus bed of New Brunswick was unrecognized, as were also the several sporadic faunas containing trilobites of the Olenellus family that had been found at a distance north, north-east and south-west of Cape Breton.

Cambrian system in Cape-Breton.

It remained then a question whether a large part of the Cambrian system was wanting in Cape Breton; or whether the older part was represented by barren measures. It is true that Mr. Fletcher, during his survey of the Cambrian district of the island, had collected small Brachiopods at several points, which had been determined by the late Mr. Billings as Obolella. But at the time of Mr. Fletcher's survey, a number of small species of different horizons that are now placed in other genera were then included in Obolella. Hence these fossils gave no certain indication (under this name) of the part of the Cambrian system to which they belonged. The task before the present writer, was to discover if these missing faunas were present in the island, and by their means and through a knowledge of the physical aspect of such rocks as might enclose them, to work out the succession of members in the Cambrian rocks and trace their distribution in the areas where such rocks were found.

Important fossils found.

Of the faunas named above, we have not been able to recognize the Protolenus fauna, but that next above it was discovered on the Mira river, in Bengal settlement, and on Trout brook. The fossils appear to belong to *Paradoxides rugulosus*, or a closely allied species. A more important discovery was made by Mr. S. W. Loper, when collecting in this part of Cape Breton for the United States National Museum. He found a Paradoxides, which the writer ascertained to be a variety of *P. Forchhammeri*, thus indicating the presence of the upper Paradoxides fauna, not heretofore certainly recognized in America. It occurs in a part of the Cambrian, which, hitherto, neither in New Brunswick nor Cape Breton, has yielded trilobite remains.

Cambrian faunas continuous.

In explorations in the valley of McLean brook, where Mr. Fletcher had found Dictyonema, the overlying fauna of Asaphellus (Tremadoc fauna) was found. This extended the faunas in Cape Breton to the summit of the Cambrian system. There still remains a blank where the fauna with Olenus and Parabolina come in, but this is simply due to the barrenness of the measures, as the strata are continuous without any break from the Paradoxides to the Peltura fauna. Thus, so far as the typical Cambrian faunas and rocks are concerned, there is a continuous and unbroken succession in Cape Breton.

Difficulty of studying basal Cambrian rocks.

In studying the basal Cambrian rocks of this island, we are confronted with a difficulty which has been an obstacle to the investigation of this series in other fields, viz., the barrenness of large masses of these rocks and the irregularity in the distribution and the localization of the limited faunas which they contain—limited not only as regards the number of fossils usually met with, but also of the few groups of the animal kingdom represented in the various occurrences. When to this is added the imperfect preservation of the fossils, it will be seen that there are many obstacles to a full and satisfactory knowledge of these ancient faunas of the basal Cambrian.

Brachiopoda and Ostracoda on Indian brook.

After searching a number of sections of these rocks with indifferent success, we were so fortunate as to discover on some branches of Indian brook, on East bay, sections that gave excellent results so far as the Brachiopoda and Ostracoda are concerned. Here the fossils were sufficiently numerous and well preserved to enable one to speak with some confidence as to the succession of forms in the Etcheminian, the conditions of their habitat, the currents prevailing during the entombment of the faunas, and the appearance and disappearance of certain types of animals during this long period.

Further, it was ascertained that there were two successive faunas in these rocks, marked by Brachiopoda and Ostracoda. If we had the trilobites we should probably have subordinate divisions of these two faunas. There is probably a third fauna in the mud-beds of the volcanic rocks beneath, which contain four or five forms different from those of the Etcheminian.

Division between Etcheminian faunas.

The line of division between the two Etcheminian faunas is at the top of the red sandstone and shales of the middle group of the Etchiminian beds. At this stage, quite a number of new species appear and displace the earlier ones. Here the genus *Acrothele* comes in. Besides being common in the Upper Etcheminian, this genus continues so in the Protolenus beds and those holding Paradoxides, and is sparingly represented in the higher Cambrian.

Value of minute fossils in determining horizons.

Among special zoological features belonging to the animals of this early time that are worthy of notice the value of minute fossils stands out with some prominence. Their importance is well shown by Tullberg's Monograph on the Agnosti. But in this case it is the minute Entomostracans and Brachiopods which yield valuable characters for determining horizons. Many of the Ostracoda of the Etcheminian beds, like those of the Protolenus fauna, had visual organs, having a prominent ocular tubercle in each valve situated close to the anterior end of the hinge line; the main adductor muscle was placed close behind it. In this they differ from the common forms of the Ordovician and Silurian rocks, in which the supposed muscle mark is toward the middle of the valve. In form, as well as in structure, their nearest relatives are those of the Protolenus beds, which follow them in natural succession. Of two new types in these faunas, one (Bradorona) is abundant in the Lower Etcheminian, and is peculiar in its shovel-shaped valves; the other with smaller but proportionately longer valves is common in the Upper Etcheminian. On the whole, the Etcheminian forms of Ostracoda are large.

A character emphasized by writers who have made the Ostracoda a subject of investigation is their social habits; they occur in swarms wherever found. Anyone would be impressed with this who has seen a cluster of Cyprids floating shell to shell in the quiet waters of a sheltered pond, and on surfaces of the shale of the Ordovician and Silurian rocks this peculiarity of habit is strikingly shown by the closely packed layers of the shells of the Ostracoda which they sometimes contain.

Habits of Ostracods.

But it is a singular fact that the writer has seen no indication of such a habit in the Protolenian and Etcheminian Ostracods. On the contrary they are always solitary, and scattered sparingly among the shells of Brachiopoda, where these last often cover whole surfaces of layers. It is also pretty certain that they had habits of burrowing and hiding. In a bed of dead shells of Brachiopods (Protosiphon) of the Protelenian time, that had been drifted on a Cambrian shore in the Kennebecasis valley, and packed together with spaces between the valves, once-living Ostracods (Beyrichona) are found, where they had sheltered themselves with their valves tightly closed, as in life. And it is common to find them thus, or with the valves partly agape in beds where the valves of the Brachiopods are scattered. These peculiarities appear to indicate a difference of habit from the later types of Ostracoda The Brachiopods, which are so abundant on some layers of the Etcheminian sediments of Indian Brook, have also yielded some facts new to science. Such small fossils as those of the genus Acrotreta are not much of a prize to the ordinary collector of fossils, for they are too small to be attractive objects in a cabinet. A few have been found and described from the Cambrian rocks. In Europe they have been referred mostly to von Seebach's species *A. socialis*; while those found in America have usually been thought to be of Billings' species *A. gemma*. (This, however, is not Cambrian but Ordovician). Externally the Acrotretas are much alike, and the almost uniform ornamentation of a fine striation concentric to the umbo, leaves little room for the discrimination of species by outward characters. In form they do not vary greatly, and in size there is little change from the earliest Cambrian to the middle of the Ordovician system.

Brachiopods.

Acrotretas.

The Cape Breton beds of the Basal Cambrian, however, not only show great variation of form, but they contain a group of species so far removed from the typical Acrotretas, that it seemed necessary to institute a separate genus (Acrothyra) for them. These peculiar forms far outnumber the typical Acrotretas in the basal beds of the Cambrian, and have two well-marked species, one of which is found in the lower, and the other characterizes the upper Etcheminian fauna.

New species.

It is by their internal characters, revealed by the mould of the shell, that these minute species are most readily discriminated; so that including the two genera Acrothyra and Acrotreta, there are about eight species of Acrotretoid Brachiopoda in place of the two or three that have been hitherto recognized.

Minute Brachiopods.

While speaking of the minute Brachiopods, one may refer to those of the genus Leptobolus—small thin shells with the lateral and central muscles far advanced toward the front, and with the vascular trunks near the margins. They thus had large visceral cavities and narrow mantle margins, both early larval characters, as may be seen by the development of *Obolus (Botsfordia) pulcher*. In both points above named they differ from typical Lingulella, which had a comparatively small visceral cavity and wide mantle borders. These little Leptoboli are found sparingly in the Lower Etcheminian, but they are quite abundant in the Upper Etcheminian beds. From this they extend up to the thin flags and shales that come beneath the Peltura fauna, being found sparingly and at intervals in the intervening measures; and they probably continue on to the typical forms in the Ordovician, described by the late James Hall. No doubt several species have been described under Lingulella.

Lingulella.

Of Lingulella proper, and of Obolus, there are two species which deserve attention, because of their considerable size among the diminutive species, which in general, characterize the Etcheminian beds; and because each is found in the mud-beds of the group, the one in the Upper and the other in the Lower Etcheminian. They have been found to appear when sandstones and grits cease to be deposited, and disappear on the recurrence of coarse sediments. In the Middle Cambrian we find species which resemble these in form and size, but they are most abundant in the sandstones and flags. The Etcheminian species referred to are *Lingulella Gregwa* and *Obolus Bretonensis*, the former of the Lower and the latter of the Upper Etcheminian fauna.

Fourteen zones.

The collections on which the above observations are based, have been made from fourteen zones or beds of the Etcheminian sediment, of which eight are in the Lower and six in the Upper Etcheminian. They therefore represent a fairly continuous succession of the Inarticulate Brachiopods, and the Ostracods, of that distant period.

Continuous history.

That the zoological history of the time was so continuous in the East bay district is to be attributed to the deposition of these Cambrian sediments in a narrow sheltered sound, and to the comparatively thin mass of sediments which the group exhibits here. Their mass did not sink sufficiently deep into the earth's crust to be changed by the internal heat of the globe, nor was it covered by heavy masses of sediment of subsequent ages. They were well protected from lateral thrust and so are not much distorted. In the thicker deposits of the

Mira valley of this age, fossils, judging by our experience, are of rare occurrence.

Trilobites. Of trilobites, good examples were found at only one locality, and these of a kind not found elsewhere in the Etcheminian. The many-jointed spined pygidea of one species are most like those of Megalaspis at the base of the Ordovician, but the head-shields do not agree with that genus. These belong to the Lower Etcheminian. A few trilobite remains, like shields of Agraulos and Ptychoparia, are found at the top of the Upper Etcheminian.

The Articulate Brachiopods are represented by a Billingsella in the Lower Etcheminian, and the Hyolithida, by the two genera, Hyolithes and Orthotheca, in poorly preserved examples, occurring at intervals in these Etcheminian beds.

Other groups. Other groups found elsewhere in the Basal Cambrian, such as Gasteropods and Lamellibranchs, remain unrecognized in the Cape Breton beds of this age. This is also the case with the Archæocyathinæ. Probably the water was too heavily charged with sediment and too much agitated to allow these to flourish.

Useful minerals. As the writer's work in Cape Breton was chiefly palæontological, its value in relation to the useful minerals was chiefly in fixing horizons where these occur and so affording the means of tracing them from one district to another. **Iron ore.** Some exploration and digging for iron ore have been made on the small streams that feed Indian brook from the north. The ore is a red hematite, and is in fahlbands, irregularly distributed in a ferriferous red sandstone. The openings exhibited much lean ore with some of better quality. This ore is in the middle division of the Etcheminian, and therefore much older than the hematite beds at Grand Mira.

It was noticed that the Upper Etcheminian on the Mira river, in a number of places, consists of fine-grained, compact gray clay-slate. When Mr. Fletcher, in his reports, speaks of gray 'argillites,' he usually means the fine rocks of this group, though sometimes the term is applied to argillites occurring higher in the Cambrian. The term is specially appropriate to the Upper Etcheminian, not only because the nature of the rock fully meets the meaning of the term used, but because to this horizon or to that of Protolenus just above, belong the slate quarries of Trinity bay in Newfoundland. Some of the slates of this age in the Mira valley may be of economic value.

Mineral deposits. In the Bretonian or upper part of the Cambrian of Cape Breton, no mineral deposits of economic value are known to me. The soft condition and ready disintegration of the rocks of this division have resulted in the production of fine soils, which add to the fertility of the Mira valley. Without this soil the farms in this valley would be stony and unproductive. The pale buff soils which they produce are in striking contrast with the red soils resulting from the degradation of the Lower Etcheminian rocks, or the stone-laden areas covered with fragments of the Coldbrook volcanic rocks, or the still older Pre-Cambrian syenites.

CHEMISTRY AND MINERALOGY.

By Dr. G. C. Hoffmann.

Chemical work.

In reporting on the work done in these branches of the Survey's operations, Dr. Hoffmann says :—'The work carried out in the chemical laboratory during the past year has been conducted upon the same lines as those heretofore followed—that is to say, it has been almost exclusively confined to the examination and analysis of such minerals, etc., as were deemed likely to prove of more or less economic value and importance. Briefly summarized it embraced :—

Various analyses.

'1. Analyses of fuels, including, among others, peat from the province of Quebec; coal from Black brook, Cochrane lake, province of Nova Scotia, from Dunsinane, King's county, province of New Brunswick, and from section 24, township 6, range 23 west of the fourth principal meridian, District of Alberta, North-west Territory; and of lignite from Little Bow river, also in the district of Alberta.

'2. Analyses of iron ores from, among other places, the west side of Middle river, Victoria county, and Cleveland, Annapolis county, in the province of Nova Scotia; the township of Sarawak, in Grey county; a short distance north of the north-east arm of Lake Temagami; Iron lake, north of the north-east arm of Lake Temagami; Turtle lake, north of the north-eastern extremity of the north-east arm of Lake Temagami, and Michipicoten, in the district of Algoma; also the township of Strange; and a point near White Fish lake, district of Thunder Bay, in the province of Ontario.

'3. Analyses in regard to nickel contents of pyrrhotite from the townships of Graham and Dowling, in the district of Algoma, province of Ontario; and from Shuswap lake, Yale district, in the province of British Columbia.

Assays for gold.

'4. Assays for gold and silver, of numerous samples of material from quartz veins in the Yukon district, North-west Territory, most o which proved to be more or less auriferous, two in particular, namely, one from a vein on the McQuesten, at a point about 120 miles above its entry into the Stewart, and another from a claim at the head of Victoria gulch, both of which contained at the rate of over two ounces of gold to the ton of 2,000 lbs. Also of samples of ore taken at different depths from a vein situate between the forks of Five-mile creek, a stream flowing into the west arm of Kootenay lake, and from other localities in the West Kootenay district of the province of British Columbia. As likewise of specimens from a quartz vein at Kiwagama lake, south-east of Abitibi post, Lake Abitibi, in the province of Quebec.

Limestones and dolomites.

'5. Analyses of limestones and dolomites, including that of a limestone from the twenty-sixth lot of the seventh range of the township of Weedon, Wolfe county, in the province of Quebec; and of a dolomite from near Brookville station, St. John county, in the province of New Brunswick. A continuation of the series of analyses of such stones which have from time to time appeared in my annual reports, in connection with an inquiry into their individual merits for structural purposes, suitability for the manufacture of lime or for hydraulic cement, or employment for metallurgical and other uses.

Natural waters.

'6. Analyses of natural waters, with a view of ascertaining their suitability for domestic or manufacturing purposes, or possible value as remedial agents, from a well in the town of Lunenburg, Lunenburg county, and from a spring on the farm of Angus Cameron, about a mile and a-half below Scotsville, on the west side of Margaree river, Inverness county, in the province of Nova Scotia; from a spring four miles from Andover, on what is called the Indian Reserve, Victoria county, in the province of New Brunswick; from a boring at Ramsay's Corners, on the eighteenth lot of the seventh concession of the township of Gloucester, Carleton county, in the province of Ontario; from a spring above West Pinchbeck, Riske creek, district of Cariboo, and from a spring at the north end of Atlin town, on the east side of Atlin lake, in the extreme north of Cassiar district, in the province of British Columbia.

New minerals.

'7. Analyses of some minerals not previously recognized as occurring in Canada, and the examination of many others, in most instances of economic importance, from localities where they were not previously known to occur, all of which will be referred to in detail in my next annual report.

Various examinations.

'8. Miscellaneous examinations, such as the examination, and, in many instances, partial analysis, of samples of bituminous shale, bog-manganese, clays, copper-ore, graphite, iron-ochres, marls, river sands for gold and platinum; silts, and other material not included under the preceding headings.

Information as to specimens.

'In addition to the work already outlined, a very large number of mineral specimens, seven hundred and five, have been received, during the period in question, for identification or analysis, or the obtaining of information in regard to their economic value. Of these, very many were brought by visitors; the greater number, however, were received from residents in more or less distant parts of the Dominion. The information required in regard to those specimens which were brought by visitors, was not infrequently communicated to them at the time of their calling, or failing that, owing to a more than mere cursory examination being necessary, or when a partial or even complete analysis was considered desirable, it was subsequently conveyed to them by letter; whilst that sought for in regard to those sent from a distance, was also, necessarily communicated by mail.

Letters and reports.

'The number of letters personally written, in connection with the work just referred to, and which were mostly of the nature of reports embodying the results of the examination, analysis or assay, as the case might be, amounted to three hundred and twenty-four, whilst the number of those received amounted to one hundred and twenty-eight

'My annual report, giving a detailed account of the chemical and mineralogical work, briefly referred to in my summary report for last year, has been written, passed through the press and is now in the hands of the binder.

'Messrs. R. A. A. Johnston and F. G. Wait, assistants in the laboratory, have, as a result of the interest taken by them in their work, and their great assiduity, accomplished a large amount of work, and proved most efficient aids. Of these,—

Mr. Johnston's work.

'Mr. Johnston has carried out a series of gold and silver assays, made many important mineral analyses, and also conducted a great variety of miscellaneous examinations. Of the mineral analyses made by him, one, in particular, calls for special mention, namely that of a mineral containing a large percentage of chromium which has recently been found in considerable quantity in the district of Lillooet, province of British Columbia. He has also recognized among some mineral specimens received for identification, a compact massive form of datolite, a mineral which had hitherto been met with in but one locality in Canada; and he has likewise identified, in some small crystals, occurring in specimens of a vein-stone collected by Mr. Broadbent, and to which my attention was drawn by the latter, the mineral faujasite, a species which had not previously been found in the Dominion.

Mr. Wait's work.

'Mr. Wait has made a number of water analyses, analyses of iron ores, manganese ores, limestones and dolomites, &c., and also conducted many miscellaneous examinations. Among the waters examined by him was one of particular interest, in whatever light regarded, namely, that from a spring at the north end of Atlin town, on the east side of Atlin lake, Cassiar district, in the province of British Columbia. This water which was very carefully and most obligingly collected and furnished by Mr. W. J. B. Pinder, of Atlin, has been shown by the exhaustive analysis of Mr. Wait to contain—disregarding for present purposes the constituents occurring in minor quantity—as much as 433·48 grains of bicarbonate of magnesia in an imperial gallon. There can be little doubt but that it is to this and similar springs that the extensive deposits of hydromagnesite occurring at the back of Atlin town site, owe their origin. The material of these deposits, as likewise the water itself, will, most probably, in the near future, receive the attention they deserve.

Mr. Broadbent's work.

'In the work connected with the mineralogical section of the museum, I have, as heretofore, been ably assisted by Mr. R. L. Broadbent, who has, apart from the general museum work—which includes the labelling and cataloguing of all newly received specimens, and the maintenance of the collection generally, in an orderly condition,—arranged and catalogued the collection of foreign minerals, which now comprises some five hundred specimens. He also spent some time in the field for the purpose of collecting cabinet specimens for the museum, and others for Mr. Willimott's use in making up collections for distribution to Canadian educational institutions. With this object in view, he visited several localities in the townships of Portland East, and Derry, in Ottawa county, province of Quebec; those of Madoc, Marmora lake, and Dungannon, in Hastings county, and that of Bagot, in Renfrew county, in the province of Ontario. He made it a special point to visit the locality of occurrence of the datolite—the mineral previously referred to, and succeeded in collecting a fine series of specimens of the same and its mineral associations. On handing these to me, he drew my attention to some small crystals which he had observed on some them. These crystals were subsequently examined and, as already stated, identified by Mr. Johnston as the somewhat rare mineral faujasite—a species new to Canada. Among other specimens collected by Mr. Broadbent, may, in addition to the foregoing, be more particularly mentioned, some interesting specimens of native antimony—a mineral not previously met with in Ontario, from the

Faujasite.

Minerals collected.

township of Madoc, and some good specimens of crystallized malachite, from the township of Dungannon. The minerals collected by him comprised :

	Specimens.	Weight.
Almandite	27	
Andradite	....	470 pounds.
Arsenopyrite	....	200 „
Celestite	....	175 „
Datolite	120	
Faujasite	6	
Fluorite	100	
Galena	135	
Graphite	12	
Hematite	....	200 „
Limestone	....	100 „
Lithographic stone	....	175 „
Malachite	6	
Native antimony	30	
Perthite	225	
Phlogopite	306	
Sandstone	....	100 „
Stilpnomelane	7	
Talc	....	100 „
Tourmaline	35	
Miscellaneous	12	

Additions to the museum.

'The additions to the mineralogical and lithological section of the museum, during the past year, embraced :—

(A.) Collected by members of the staff or others engaged in field-work in connection with the Survey :—

Bailey, Professr L. W. :—

a. Eighteen fragments of material referred to as copper ore, from a pit at Chester, Albert county, N.B.

b. Fourteen fragments of material from the Colonial copper mine, near Dorchester, Westmoreland county, N.B.

c. Two fragments of cordaite shale from two miles above Dalhousie, Restigouche county, N.B.

Barlow, Dr. A. E. :—

a. Danaite from the township of Graham, district of Algoma, O.

b. Corundum from the township of Raglan, Renfrew county, O.

Johnston, J. F. E. :—

Molybdenite and bismuthinite from Lake Kewagama, Q.

McConnell, R. G. :—

Additions to the museum.

a. A specimen of asbestiform actinolite from the Klondike river, Yukon district, N.W.T.

b. A specimen of rutile from Thistle creek, Yukon district, N W.T.

(B.) Received as presentations.

Barlow, Dr. A. E., Geological Survey :—

Corundum from Montana, U.S.

Bulpit, C. H., Malone, Hastings county, O. :—

Magnetite from lot 17, con. XI., Marmora, Hastings county, O.

Burke, D. F., Port Arthur, O.

Coal from near Blairmore, Crow's Nest Pass Railway, Alberta, N.W.T.

Canada Paint Company, Montreal, Q. :—

Iron ochre from Cap de la Madelaine, Champlain county, Q.

Chambers, R. E., Bridgeville, N.S. :—

a. Barite crystals from Bridgeville, Pictou county, N.S.

b. Limonite from Bridgeville, Pictou county, N.S.

Craig, B. A. C., Canada Corundum Company, Toronto, O. :—

Twenty samples of dressed corundum from the Craig mine, Raglan, Renfrew county, O.

Harrison, J. E., Madoc, O. :—

Talc from Huntingdon township, Hastings county, .

Holmes, N. D., Ottawa :—

Mica from Dakota, U.S.

Hopkins, W. H., Hamilton, O. :—

Auriferous quartz from the Mikado mine, Lake of the Woods, district of Rainy River, O.

Kirkgaard, P., Canadian Gold Fields Company, Delora, O. :—

Auriferous quartz from the Florida mine, and auriferous quartz (Ribbon quartz) from the Last Chance mine, Mogollon Mountains, New Mexico, U.S.

Additions to the museum.

Low, A. P., Geological Survey, Ottawa, O. :—

a. Scheelite, rose quartz, and quartz crystals from Japan.

b. Petzite from Calgoorlie, West Australia.

c. Noumeaite and Garnicrite from New Caledonia.

Moberly, G., and C. Cameron, Collingwood, O. :—

Marl from lots 25 and 26, con. VII and VIII, Flos township. Simcoe county, O.

Moon, Albert, Madoc, O. :—

Specimen of native antimony from the Dufferin mine, Madoc, Hastings county, O.

Morrison, Murdoch, Renfrew, O. :—

Zircon, from the township of Westmeath, Renfrew county, O.

McEvoy, James, Fernie, B.C. :—

Erythrite from the Crow's Nest branch of the Canadian Pacific Railway, between Creston and Kootenay Landing, West Kootenay district, B.C.

McNaughton, G. W., General Electric Mining Company, Sydenham, O., per Dr. R. W. Ells :—

Mica (phlogopite) 33 by 24 inches, from lot 11, con. VII, Loughborough, Frontenac county, O.

Rust, Randolph, Port of Spain, Trinidad, West Indies :—

Asphalt and petroleum from Aripero, Trinidad, W. I.

Scott, W. D., Winnipeg, Man. :—

Petzite from the Boulder Perseverance claim, Calgoorlie, West Australia.

Shirley, F. S. Glenalmond, Q. —

Mica (phlogopite) from Portland East, Labelle county, Q.

Stewart, James, Grande Prairie, B.C. :—

Calcareous tufa, actinolite, andradite and tremolite

Wallbridge, C. M., Madoc, O. :—

Group of calcite crystals from the Wallbridge mine, Madoc, Hastings county, O.

Additions to the museum.

Winning, Bush, Glenalmond, Labelle county, Q. :—

Mica (phlogopite) from the township of Derry, Labelle county, Q.

In addition to the foregoing, there has also been added to this section of the museum :—

109 specimens of rocks, with microscopic sections, from the Yukon district, N.W.T., collected by R. G. McConnell.

56 specimens of rocks, with microscopic sections, from the Atlin district, B.C., collected by J. C. Gwillim.

226 specimens of rocks, with microscopic sections, from the East coast of Hudson Bay, Ungava district, collected by A. P. Low.

58 specimens of rocks, with microscopic sections, from Great Slave lake, Mackenzie district, collected by Dr. R. Bell and J. M. Bell.

15 specimens of rocks from Great Slave lake, collected by J. W. Tyrrell.

8 specimens of rocks from the West coast of Hudson Bay, Keewatin district, collected by D. T. Hanbury.

Mr. Willimott's work.

Educational collections supplied.

'Mr. C. W. Willimott was engaged during the early part of the year in going over, arranging, and taking stock of the collection of minerals under his charge and employed by him in the making up of collections for distribution, in order to ascertain what further material it would be necessary to procure in the course of the summer, to make good deficiencies. This accomplished, he visited, for the purpose specified, numerous localities in the townships of Hull, Templeton, Wakefield, Wright, and Egan, in Ottawa county, province of Quebec; subsequently, certain localities in the township of Grenville in Argenteuil county, Bolton in Brome county, Ascot in Sherbrooke county, Coleraine and Thetford in Megantic county, and Broughton in Beauce county, in the province of Quebec; and finally, localities on the East River of Pictou, in Pictou county, Parrsborough, Partridge Island and Two Islands, in Cumberland county, Kingsport in King's county, and Hantsport and Windsor in Hants county, in the province of Nova Scotia.

Minerals collected.

'In the prosecution of this work he succeeded in collecting a large and varied assortment of minerals. The same comprised :—

	Specimens.	Weight.
Agate	....	250 pounds.
Analcite	80	
Amygdaloid	....	200 "
Apatite, crystals in matrix	140	
Chabazite	200	

	Specimens.	Weight.
Chromic iron		450 pounds.
Chrysotile (asbestus)		75 "
Chrysotile, in serpentine		300 "
Gypsum, fibrous		200 "
Heulandite	120	
Hornblende schist		300 "
Lepidolite		50 "
Limestone		200 "
Limonite		650 "
Phlogopite	60	
Picrolite		150 "
Quartz crystals	900	
Scapolite		175 "
Steatite		200 "
Stilbite	150	
Strontianite		350 "
Tourmaline	123	
Miscellaneous	30	

'In addition to the above minerals, Mr. Willimott has received, for making up collections:—

Presents

Coal, of the Carboniferous, presented by E. Hargreaves, Esq., Manager of the Springhill Coal Mines, Nova Scotia, 200 pounds.

Corundum crystals, in the matrix, presented by B. A. C. Craig, Esq., Canada Corundum Co., Toronto, Ontario, 2000 pounds.

Gypsum, presented by C. J. Osman, Esq., Manager of the Albert Manufacturing Co., Hillsborough, Albert county, New Brunswick, 300 pounds.

Educationa collections.

'Prior to Mr. Willimott's leaving for the field, and since his return, he has, for the most part, been engaged in making up collections for distribution to various Canadian educational institutions. The following is a list of those to which such collections have been sent:—

High School, Paradise, N.S	consisting of	100	specimens.
Public School, Rainham Centre, O	"	100	"
Waller Street School, Ottawa, O	"	100	"
Public School, Nelson, B.C	"	38	"
High School, Gananoque, O	"	125	"
Broadway School, Woodstock, N.B	"	125	"
High School, Carleton Place, O	"	125	"
Normal School, London, O	"	125	"
High School, Wood's Harbour, N.S	"	125	"
Collegiate Institute, Whitby, O	"	125	"
High School, Newmarket, O	"	125	"
High School, Westville, N.S	"	125	"
Grand Falls Superior School, Grand Falls, N.S.	"	125	"
High School, Pembroke, O	"	125	"
High School, Rodney, O	"	125	"

'In addition to which the undermentioned have been supplied with :—

McGibbon, R. D., Montreal, Q.	1	specimen.
Collegiate Institute, Napanee, O.	1	"
Guerra, René, Paris, France	30	"
Wright, W. G. Hawkesbury, O.	1	"
Fisher, Hon. S., Ottawa, O.	1	"

THE PROGRESS OF MINING IN CANADA IN 1901.

Mr. E. D. Ingall, Mining Engineer to the Department.

Review of mining industry.

In reviewing the progress of mining in Canada, only the general features can be pointed out, as no detailed and reliable data are available until after the close of the year.

Gold.

The gold-mining industry naturally calls for attention first, accounting as it does for nearly half the value of the mineral product of the country. No very startling developments were presented during the year as far as the eastern part of Canada is concerned. In Nova Scotia the mines operated upon the quartz leads are practically all long-established enterprises, and the industry with slight fluctuations, pursues year by year the even tenor of its way. The mining of the alluvial gold in Quebec province, remains still in abeyance. In Ontario there is not much to note. In this province are many belts of the rocks shown as Huronian on the maps of the Survey, which in the aggregate constitute a large area of this metalliferous series. As railway construction makes the outlying portions of the province easier of access, more vigorous and thorough search over these areas by the prospector will doubtless reveal many other gold-bearing veins, so that future years promise to show a steady extension of operations in this province. Whilst the output of gold from the Yukon placers hardly comes up to that of 1900, doubtless other rich districts will be found in future years in other parts of this extensive country. The reports of finds of rich gravel in some of the older districts of British Columbia, where the richer placers had been supposed to have been worked out years ago, show that unexpected discoveries of great importance may be made at any time in a young and undeveloped country such as this. Apart from the production of gold from the shallower placer deposits, the progress in hydraulicing, etc., as well as in vein-mining, is steady, with every chance of continued advance in future years.

The grand total of the production of gold in Canada owes much also to the operations in the mining and smelting of the pyritous ores of Southern British Columbia, the rapid growth of which in late years will have an important effect.

Copper. The larger proportion of the copper production of Canada results also from the operations on these deposits of mixed sulphide ores, not only in the districts of East and West Kootenay and Yale, but also in the coast sections of British Columbia, and the largely increased activity in this respect will result in a considerable augmentation of the copper output of the country, which result will be still further enhanced by the growth of the mining industry located in the Sudbury district. The interest which has of late been taken in the copper ore deposits of the Huronian district between Bruce Mines and Sault Ste. Marie, resulting in the reopening of the old mines at the former place and the exploitation of similar deposits in the surrounding district, is an interesting feature of the present copper situation. The long-established mines in the Eastern Townships of Quebec province can be reckoned on as constant contributors, and word comes to hand as to increased interest and activity in exploration in the Maritime provinces. Taken as a whole, the copper industry of the Dominion has exhibited many satisfactory features which should show when the figures of production become available later.

Nickel. The nickel industry of Sudbury district has also many encouraging features to record. The inauguration of the works of the Mond Co., of the Nickel-Copper Co. of Hamilton, and of the Orford Copper Co. give evidence of the general prosperity, resulting in greater activity in smelting as well as in mining and prospecting.

Lead. Unfortunately the lead industry, which, with the exception of small amounts produced in the east, is practically confined to British Columbia, has suffered a considerable set-back. The operators of the Slocan and other galena mines in the south-western part of the province have found themselves largely debarred from their chief market in the United States, owing, it is said, to difficulties regarding freight and smelter rates, so that production of this metal will have suffered a very considerable falling off. The authorization of the payment of a bounty by the Dominion Government for the next five years on all lead refined in Canada from materials produced in Canadian smelters from Canadian lead ores, may perhaps lead to the installation in the country of works for this purpose and so relieve the situation by rendering the home mines independent in this respect. The price of lead also has been somewhat lower than the average for 1900, tending to further depress the situation.

As such a large proportion of the silver production of the country is represented by that contained in the argentiferous galena mined in British Columbia, the depression in the lead industry will also affect the output of silver. Silver.

One of the most hopeful features of the progress of the mineral industry during 1901 is to be found in the advance which has been made in the important branches of coal and of iron mining and smelting. The new departure made at Sydney, Nova Scotia, in the inauguration of the two large iron and steel plants of the Dominion Iron and Steel Company and the Nova Scotia Steel and Coal Company respectively, will doubtless lead to most important results, not only in enlarged mining of coal and the making of coke for consumption in the iron works, but also doubtless in the establishment of other important accessory industries, such as ship-yards, bridge works, &c. All over the country, increased interest has been shown in the question of our resources in iron ores, and even in British Columbia, where iron has been quite an unimportant factor in the past, much greater attention is being paid to exploration for these ores. The opening up of the Crows Nest Pass coal fields and the considerable enlargements made and contemplated in the coking plants of the companies operating them, is a fact of the greatest importance, especially to the smelter interests already established or about to be inaugurated in the west, and we may look forward to the opening up of yet other areas of Cretaceous coal in this region as extensions of the railways bring them within the sphere of working conditions. Coal and iron. Development at Sydney N.S.

An epoch-marking episode is to be noted in the shipments of Canadian pig iron from Cape Breton to Glasgow, Scotland, at prices, it is said, admitting of successful competition there, even with Scotch pig. The importance and promise of the iron and coal industries of our eastern seaboard, have begun to attract notice, and in a contribution to the *Colliery Guardian*, Sir Christopher Furness, the well-known English authority, draws the attention of his countrymen to many important features. He points out the unexcelled shipping and loading and unloading facilities both with regard to the ore supply at the Newfoundland mines and at the works and mines in Cape Breton. Also, that the excellent arrangements and the extensive use of machinery result in a much larger output per man and a much smaller cost of production than is possible under the present conditions of the British collieries, so that with the advantages possessed, 'with two splendid harbours and no high railway rates for carriage to the water, also with an unlimited supply of coal, they are in a position to produce and deliver f. o. b. at a figure quite out of the question for any of our Canadian pig iron for Scotland.

collieries to compete with.' He further expresses the opinion that the coal from this point will be bound to enter into competition 'with our north and south country coal in the Mediterranean markets,' also that 'This company can deliver coal f. o. b. at less than $1 per ton. The steel company will be able to make pigs at less than $6 per ton; steel blooms at less than $10 per ton, and steel rails at about $12.'

Iron smelting.

The possibilities of iron smelting in the central parts of Canada are being demonstrated in the continued operation of smelters at Deseronto, Hamilton and Midland, in Ontario, whilst the inauguration of the contemplated iron and steel plant at Sault Ste. Marie will be a most important feature in the industry. The works in this province still use a very large proportion of foreign ore, but the increased output from the Michipicoten district would seem likely to inaugurate a brighter era.

To the metal and coal-mining industries, already alluded to, must be credited about 85 per cent of the value of the total mineral production of the country. Regarding the non-metallic mineral output contributing the other 15 per cent, there is nothing very unusual to report, although there are some interesting points worthy of note.

Graphite.

After some years of depression, the graphite industry carried on in western Quebec, seems to be in a fair way to be placed on a permanent basis. Work was prosecuted at the deposit at Calumet and some selected mineral was shipped. The North American Graphite Company worked during most part of the year and shipped a number of car loads of the finished product of its mill. It is hoped that the investigations and experiments during past years, made by this company, have resulted in such improvements in the methods and machinery for the treatment of the rock that the difficulties encountered in the past will no longer debar the development of the extensive deposits of graphite-bearing rock of the vicinity. In Ontario, the Ontario Graphite Company has been taking steps to extend its operations by erecting a mill for the treatment of the ore.

Asbestus and mica.

Natural gas.

In asbestus, the mines have been operated as usual. The mica mines had to contend with dullness of the trade and accompanying low prices. In the inter-lake peninsula of Ontario, as in past years, a number of bore-holes were put down in connection with the operation of oil and gas fields and a few pools of oil were thus located. Difficulties begin to be met with in regard to the supply of natural gas, the pressure being said to have lessened rapidly during last year in the Essex field and trouble with water in the wells having been encountered. It is claimed, however, that so far there has been no serious falling off of pressure in the Welland field. An effort is being made by the Provincial Government to prevent the export of this fuel to the United States, where most of it has so far been consumed, but without success so far, owing to legal difficulties encountered in trying to apply the law.* This failure is regrettable, as gas to the value of nearly three million dollars since the commencement of the industry, rating it at a very low price per thousand, has been produced, the greater part of which went to build up industries outside of Canada, which gained very little proportionately by the exploitation of this mineral asset of the country. Some little attention was paid to the further exploration of the North-west Territories for gas with results which have, so far, not transpired.

Export of gas.

In the cement industry, considerable activity has been shewn in the formation of new companies and the erection of new works for the manufacture of Portland cement, chiefly in Ontario. As this industry naturally connects closely with the general prosperity of the country its rapid growth of late years is a most encouraging sign.

Portland cement.

The central portions of the Dominion being unfortunately lacking in any supply of coal, the growing interest taken in the utilization of the large resources in peat is of great importance. At several points, works are in operation or being erected, including the large and important plant of the Trent Valley Peat Company, near Peterborough, Ontario.

Peat.

It is gratifying to note also that the corundum deposits are still being developed. The existence of corundum in Ontario was pointed out some years ago by officers of the Geological Survey. The Canada Corundum Co. worked its mill the greater part of the year. The plant is capable of turning out three tons of pure corundum per day. These operations have resulted also in showing that the material can be properly graded. Operations were also carried on in the same vicinity by another company, regarding which no particulars are to hand.

Corundum.

As usual, inquiries have been made at the Department regarding a number of mineral substances which are of economic value or are becoming so. A list of these has already been given in the first part of this report. Among the more important and interesting are platinum, felspar and molybdenite. There has been a small production of platinum in British Columbia for many years, but of late this has fallen off. It was obtained in connection with the placer washings on the Similkameen river. Now, however, that the demand has so

Platinum.

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* The above was written in December last. Since that time exportation has been stopped.

increased and that the prices quoted give it a higher value than gold, it is hoped vigorous prospecting will result and that further deposits may be found. Important data regarding the geological conditions which may be taken as indicative of the most likely places to look for the metal, will be found in the remarks of Mr. R. Brock in this report, and in the forthcoming advance statement of this Section it is intended to give further information bearing on the subject.

Molybdenite.

The demand for molybdenite at good prices still keeps up, so that with the discovery of workable and accessible deposits, a new industry could be inaugurated. This mineral is of common occurrence in the Laurentian rocks of Eastern Canada and discoveries are also reported from British Columbia. At no point, however, has it, so far, been developed sufficiently to prove its existence in commercially workable quantity. It seems to occur mostly as disseminated crystals in quartz veins, and where the larger and thicker foliated crystals are plentiful, it would seem that profitable extraction by crushing and hand picking should be possible in view of the prices offered, viz. $200 to $250 per ton for the pure mineral. With regard however to the class of ore carrying the mineral evenly disseminated in small flakes, as is so often the case, difficulty would probably be experienced in making an efficient separation by the usual methods of ore-dressing, the flakes being apt to float away with the lighter gangue material. The results of experiments to test this, which were made at McGill University mining laboratory, are given in the Summary Report of the Director of the Geological Survey for 1900.

In the foregoing remarks no effort has been made to give other than a sketch of the main features of the mineral industry of the country, viewed as a whole, for the year 1901. Many details will be found in the accompanying reports of the different field officers of the Survey for the various districts, and in the full report of the Mines Section to be published later in the year, will be found the detailed statistics and technology of each mineral industry.

MAPPING AND ENGRAVING.

C. O. Senécal, Geographer and Chief Draughtsman.

Report of Geographer and Chief Draughtsman.

have the honour to report as follows on the work carried out under my supervision during the period which has elapsed since January 1, last. The staff has been increased in number since June 1, and at present ten map-compilers and draughtsmen, including four field-assistants, who also attend to mapping when not actually employed in field work, are engaged in compiling and putting in shape for publication, parts of the field work and maps hitherto left in arrear, and in attending to the current work of the office. Staff.

During the past summer, several of these men having been sent to the field as usual, the work they had in hand, was, of course, temporarily stopped. The Klondike topographical and geological map and several sheets of the Ontario and Nova Scotia series have thus been delayed, but these will be resumed at the earliest date possible and will likely be ready for publication during the course of the winter.

Routine work.

The routine work, including laying down geographical projections, correcting proofs of maps and reports, making tracings and drawings for office and field use, supplying information to the librarian, preparing various memoranda in reference to the reproduction of maps, engravers' accounts and other subjects, has been distributed among the staff and attended to.

The assignment of work has been as follows :—

Assignment of work.

Mr. L. N. Richard has drawn for reproduction by engraving, the Manitou Lake sheet, No. 4, Western Ontario series; has prepared for lithography the coloured copies of the Trafalgar and Stellarton sheets, Nos. 42 and 43, Nova Scotia series. A list of place-names covering the map of the Atlin mining district, B.C., for the Geographic Board was made by him, and he also reduced part of Dr. R. Bell's astronomical observations made in Baffinland. During my absence from the office on field duties, his time was spent in cataloguing maps, making reductions of railway and other plans for field use, supplying information to the librarian and in general draughting work. He has now in hand the revision of the map of the district around Bancroft, Ontario. For the purpose of completing the western portion of this sheet, he was sent on August 16, to meet Dr. F. D. Adams in the field, and under the latter's instructions to make micrometer surveys along several roads in the townships of Glamorgan, Monmouth, Cavendish and Anstruther. He returned to this office on September 9.

Mr. W. J. Wilson, who last year had accompanied Dr. R. Bell, in the Michipicoten region, was occupied in laying down on the scale of publication, the material gathered for sheets 143 and 156, Ontario series, covering part of that district. He also attended to general draughting work required in the office. He left for the field accompanied by Mr. J. F. E. Johnston, under instructions from the director on June 10, and both returned on October 20. The above mentioned compilation will be resumed by Mr. Wilson as soon as he has completed his report on this summer's work.

Mr. J. F. E. Johnston will continue the topographical mapping of the Klondike sheet, which will probably be completed and ready for publication before the end of the present calendar year.

Mr. E.O. Prud'homme has had charge, as in former years, of the maps held in stock for sale and distribution. Besides making several drawings for office and field use, he has drawn and lettered for the engraver the following maps and plans, viz., maps of the city of Ottawa and vicinity in Ontario and Quebec, and of the Atlin mining district, B.C., plans of Montague and Waverley gold districts in Nova Scotia, and partly the East Kootenay sheet, B.C. He has also spent some time in labelling rock specimens, etc. A series of diagrams showing the mineral productions of Canada, and five sketch-maps of new explorations are also being drawn by him for photo-lithographing.

Special map for Pan-American Exhibition.

Mr. J. Keele has compiled the greater part of sheets 119 and 122, Ontario and Quebec series, and constructed a special wall map of parts of the counties of Frontenac, Renfrew, Lanark and Leeds, for the Pan-American Exhibition. This map was prepared on the scale of two miles to 1 inch, in response to a request from the Kingston Board of Trade, but was not, however, intended for publication. Mr. Keele was away on leave of absence from February 26 to April 23, and left for the field as assistant to Mr. R. G. McConnell in the Klondike region in the beginning of June. He returned to this office on October 15 and will resume his work on the Ontario sheets as soon as he shall have completed the sketch-maps of the exploration of 1901 in the Yukon district, which he is at present compiling for the Summary Report.

Mr. H. Lefebvre continued the compilation of the Lake Nipigon sheets, attended to the cataloguing of maps, plotted sheets, note-books, &c., and was employed on general draughting work until he left the Geological Survey on April 1.

Mr. W. H. Boyd completed the compilation of the geological map of Atlin mining district (No. 742). He was detached to assist Mr. D. B. Dowling in the field from May till October, and since his return has been occupied in reducing astronomical observations, compiling a small sketch-map of the past summer's exploration in Keewatin for publication in the Summary Report and in plotting his survey.

Mr. J. A. Robert, who, a few years ago, had in this department acquired some experience in map-compiling was re-employed and since

May 7 has been occupied in mapping Mr. H. Fletcher's surveys, covering sheets Nos. 59 to 63 and 76 to 79, Cumberland county, Nova Scotia.

Mr. Owen O'Sullivan was employed on general work from April 13 to 29. He has since been occupied in reducing and compiling Mr. E. R. Faribault's surveys made in Halifax county, Nova Scotia, on sheets Nos. 53, 54, 67 and 68. During the summer he was instructed to accompany Mr. Faribault to Nova Scotia and there to continue this work, the nature of which required this officer's personal supervision. Mr. O'Sullivan also assisted me in the field from July 18 to August 7.

Mr. Paul Frèreault has been employed in this office since June 3. He has drawn on autographic paper for lithography a series of thirteen maps of mines, intended to illustrate the report of the Mining Engineer of this Department, on the iron ore deposits of the district traversed by the Kingston and Pembroke railway, Ontario. He reduced and transferred from the Admiralty chart, the coast of Nova Scotia from Halifax to St. Margaret's bay for map-sheets Nos. 68 to 71, the compilation of which will be undertaken at an early date. He also made several tracings and reductions of railway and other plans for field and office use, and he is at present completing the southern portion of sheet No. 121, Ontario and Quebec, from Dr. R. W. Ells' surveys made in 1900.

Mr. Vincent Perrin has been employed in this office since October 15, and is now making a tracing for the engraver of the map of the Grass River region north of Lake Winnipeg, and attending to general draughting work.

Mapping by field-officers.

The following maps have also been compiled and drawn by field officers from their respective surveys:—

Grass river region, Keewatin, scale 8 miles to 1 inch, by Mr. D. B. Dowling.

East coast of Hudson Bay, Ungava, scale 8 miles to 1 inch, by Mr. A. P. Low.

West Kootenay sheet, B.C., scale 4 miles to 1 inch, by Mr. W. W. Leach.

East Kootenay district, B.C., (preliminary sheet) scale 4 miles to 1 inch, by Mr. J. McEvoy.

Crows Nest coal-fields, B.C., scale 2 miles to 1 inch, by Mr. J. McEvoy.

Mr. J. M. Bell mapped his exploration of Great Bear lake and route between this lake and Great Slave lake, on a scale of 8 miles to 1 inch.

A map of the northern portion of Labrador peninsula, compiled from recent explorations and sketches from natives, has been received from Mr. A. P. Low, and will appear in the Summary Report for the present year. Although not published as a geological map, it will add to our knowledge of the geography of this almost unexplored region.

The West Kootenay sheet, British Columbia, which has been sent in parts to the engraver since 1898, has been completely engraved. Proofs have been received and the geologically-coloured copy is being prepared. This sheet is of the same scale and covers the same area as the Kamloops and Shuswap sheets, namely 80 miles square.

Size of British Columbia sheets reduced.

While British Columbia is fast developing its mineral resources, the difficulty of accurately mapping the geology and topography of its southern portion necessitates surveys which, on account of the mountainous character of the country, cannot be made as quickly as surveys elsewhere in Canada, and the time spent in the compilation of such large geological sheets is very considerable. It seems desirable in order to bring them before the public within reasonable time, that smaller map-sheets should be drawn. It is therefore suggested that the size of the sheets of the British Columbia series be reduced to one-half their original area by drawing an east and-west line through the centre of each, as shown on the accompanying index-map. An obvious advantage is that the sheets of greatest economic importance could be executed first and published without delay.

Dominion map.

The engraving of the eastern half of the Dominion map on the scale of 50 miles to 1 inch, has been completed, and the eleven colour-stones for the western half were prepared and proved, but the publication of this sheet has been delayed on account of important geological information relating to the Klondike, Great Bear lake and Great Slave lake regions, received since, and involving material changes on several of the colour-stones.

Accompanying sketch-maps.

A number of sketch-maps are being prepared for publication in the present Summary Report to illustrate part of the progress made in the field during the past summer. These maps, although quickly compiled, are sufficiently accurate to meet immediate requirements and will supply valuable information, pending final adjustment and compilation of the surveys on our regular serial sheets.

Cataloguing.

The cataloguing of maps, survey records, etc., is attended to by the staff. More space and a few presses and cabinets are desirable, in which to store conveniently the accumulated manuscript maps and other records.

Geographic Board.

Numerous Geographic Board meetings were attended and lists of place-names covering parts of the Atlin, West Kootenay and Grass river sheets were submitted for approval.

Publication of Nova Scotia sheets.

The publication of sheets 42 to 48 and 56 to 58, Pictou and Colchester counties, N.S.,—deferred on account of certain geological points requiring final settlement—was decided upon by the director and the edition of sheet No. 42, (Trafalgar sheet) has been received from the printer.

Field work by geographer.

From July 15, to August 7, my time was spent in the field. For the purpose of laying an accurate base-line on sheets Nos. 67, 72 and 73 of the Nova Scotia series, upon which to tie the detailed surveys of Mr. E. R. Faribault—which are now ready for the compiler—a transit and chain line was run along the Intercolonial and the Dominion Atlantic railways from Bedford Basin to Hantsport, connecting the opposite coasts of Nova Scotia. From the data of this survey, the following points were determined:—

Locality.	Latitude.			Longitude.			Magnetic Declination.
	°	′	″	°	′	″	
Bedford station (I.C.Ry.).	44	43	43	63	39	54	
Windsor junction	44	47	12	63	38	25	
Beaver Bank station (D.A.Ry.)	44	47	46	63	41	28	
South Uniacke station	44	52	10	63	47	20	
Mount Uniacke station	44	53	29	63	49	50	
Stillwater station	44	55	2	63	57	10	
Ellershouse station	44	56	45	64	0	26	20° 16′ W.
Newport station	44	57	41	64	3	26	20° 37′ W.
Windsor station	44	59	49	64	8	16	
Hantsport station	45	4	5	64	10	40	

The above latitudes and longitudes depend on the position of the Halifax navy yard flag staff as given on Admiralty charts Nos. 311 and 2320.

The magnetic declination was ascertained at every station, but those observations only which were free from possible local disturbance are here recorded.

Maps etc., published.

Twenty-eight maps, one sheet of sections, four profiles and seven diagrams, published during the period covered by this report, are enumerated below:—

Catalogue Number.	Maps, Sections, Profiles and Diagrams.	Area in Square Miles.
752	Yukon District—Salmon river gold fields—Scale, 2 miles to 1 inch.	138
753	" Sixty-mile river gold fields—Scale, 6 miles to 1 inch.	
711	British Columbia—Atlin gold fields (preliminary edition)—Scale, 6 miles to 1 inch.	4,920
759	" Sections of coal-measures, Crows Nest coal fields—Scale 300 feet to 1 inch.	
751	Keewatin—Exploration of Ekwan and Trout rivers and west coast of James bay—Scale, 50 miles to 1 inch.	
758	Ungava—Sketch map of northern interior of Labrador peninsula—Scale, 50 miles to 1 inch.	
	Ontario—13 maps illustrating the mode of occurrence of iron ore deposits in eastern Ontario, viz. :—	
726	Bedford and Glendower mine—Scale, 400 feet to 1 inch...	
727	Robertville and Mary mines—Scale, 200 feet to 1 inch.. ..	
728	Fournier mine—Scale, 200 feet to 1 inch	
729	Christie lake mine—Scale, 200 feet to 1 inch	
730	Wilbur mine—Scale, 200 feet to 1 inch......	
731	Yuill mine—Scale, about 37 feet to 1 inch....	
732	Bluff point mine—Scale, 400 feet to 1 inch.	
733	Calabogie mines—Scale, 200 feet to 1 inch............	
734	Culhane mine—Scale, 200 feet to 1 inch	
735	Black Bay or Williams mine—Scale, 120 feet to 1 inch.....	
736	Chaffey and Matthew mines—Scale, 600 feet to 1 inch	
737	Playfair or Dalhousie mines—Scale, 50 feet to 1 inch......	
738	Dog lake mine—Scale, 50 feet to 1 inch....	
714	Ontario and Quebec—City of Ottawa and vicinity—Scale, 1 mile to 1 inch.	450
760	" " Sketch map of Lake Abitibi region—Scale, 16 miles to 1 inch.	
593	Nova Scotia—Sheet No. 42 (Stellarton sheet)—Scale, 1 mile to 1 inch.	216
709	" Mt. Uniacke gold district—Scale, 250 feet to 1 inch	
721	" Waverley gold district—Scale, 250 feet to 1 inch.	
764	" Geological sketch map of parts of Hants and Kings counties—Scale, 2 miles to 1 inch.	
	Four profiles to accompany report on altitudes, viz. :—	
746	Profile No. 1—Canadian Pacific Railway—Montreal to Winnipeg.	
747	Profile No. 2—Canadian Pacific Railway—Winnipeg to Vancouver.	
748	Profile No. 3—Canadian Pacific Railway—Old location via Yellowhead Pass.	
749	Profile No. 4—River St. Lawrence and Great Lakes.	
754-757	Four index maps—Part of British Columbia, Western Ontario, New Brunswick and part of Quebec, and Nova Scotia—Scale, 50 miles to 1 inch.	
	Also seven diagrams showing mineral production of Canada.	

There are at present nineteen maps and plans in the engraver's hands or in press and about forty others at different stages of progress, nine of which have been completely compiled and will soon be ready for the engraver. Maps in progress.

The accompanying index-maps, showing the progress of the mapping up to date, are intended to be distributed with the List of Publications. Index maps.

The examination and repairing of the field instruments has been as usual, attended to, and I beg to report that several micrometers, aneroid barometers, chains, cameras, prismatic compasses and nearly all the compass-tripods are practically worn out, and should soon be replaced. Field instruments.

Since January the following instruments were purchased:—

One cyclotomic mountain transit and tripod, No. 14, from A. Lietz & Co., San Francisco, Cal.

One Hadley sextant, No. 7, from Cary, London, Eng.

One Abney level, No. 15 " "

Three prismatic compasses, Nos. 64, 65, 66, from Cary, London.

One 300-ft. steel band, No. 22, from W. & L. E. Gurley, Troy, N.Y.

Two 66-ft. steel bands, Nos. 23 and 24 " " "

One surveyor's compass and tripod, No. 15, from Keuffel & Esser, New York.

One watch, No. 13, from Henry Birks & Son, Ottawa.

The number of official letters, memoranda, &c., relating to map-work, sent and received was 260 and 150 respectively. Correspondence.

PALÆONTOLOGY AND ZOOLOGY.

Dr. J. F. Whiteaves.

Dr. Whiteaves reports that 'the manuscript of the "Catalogue of the Marine Invertebrata of Eastern Canada," commenced in the fall of 1899, was completed in May last. In order to give the latest information on the subject, a considerable portion of the manuscript was rewritten in the early part of 1901. The catalogue was published on 24th of August last, the greater part of two months having been occupied in seeing it through the press. In its printed form it consists of 272 pages, large octavo, with two illustrations in the text. With the exception of the jelly-fishes and a few small crustacea, nearly all the Catalogue of Marine Invertebrata.

Number of species.

species enumerated in it are from the sea bottom, at various depths, and most of them were obtained by dredging. The number of species of invertebrata from the seaboard of Eastern Canada south of the Baie des Chaleurs that have been determined or described up to August, 1901, would seem to be 1,064, as follows:—

Protozoa	64	species.
Sponges	36	"
Coelenterata	119	"
Echinodermata	71	"
Marine worms (Annulosa)	138	"
Brachiopoda	3	"
Polyzoa	115	"
Mollusca	282	"
Crustacea	198	"
Pycnogonida	11	"
Chordata	27	"
	1,064	species.

'As remarked by Dr. Bell in his letter of introduction to this catalogue, "it is hoped that the latter will act as a stimulus to renewed activity in the study of marine zoology, and that it will be of use not only to zoologists but also to students of the fossils of the post-tertiary deposits of the eastern portion of the Dominion."

"Mesozoic Fossils."

'The manuscript of the fifth and concluding part of the first volume of "Mesozoic Fossils" was commenced in September (1901), and about fifty pages of it have been written. The part will probably be completed and ready for the printer early in the spring. It is intended to consist of descriptions or identifications of numerous additional species or specimens of fossils from the Cretaceous rocks of Vancouver and adjacent islands, with a revision of the fauna of these rocks up to date. It will be based upon material that has been accumulated during the last five years, including 160 specimens of Vancouver Island fossils recently received from Mr. Walter Harvey, and about 100 from the Rev. G. W. Taylor, all of which have been examined and studied.

Mollusca from Ungava.

A paper entitled "Notes on some Land and Fresh-water Mollusca from Fort Chimo, Ungava Bay, Ungava," has been prepared and published in the *Ottawa Naturalist* for March, 1901. Another paper entitled "Note on a supposed new species of *Lytoceras* from the Cretaceous rocks at Denman Island, in the Strait of Georgia," has been written and published in the same journal for May, 1901.

Other work.

'At the request of Section IV of the Royal Society of Canada, a Bibliography of Canadian Zoology for the year 1900 has been compiled and presented to the Society, at its last meeting, for publication in its Transactions for 1901.

'A collection of exotic shells has been named for the Museum of Ottawa University and a set of duplicates of recent Canadian marine shells, mostly from the coast of British Columbia, has been selected, labelled and presented to the same museum.

'In all, some thirty-three small collections from various localities, have been examined and reported upon provisionally during the year, and answers, as usual, have been written to many inquiries for information on various palæontological and zoological topics.

'During Dr. Bell's absence in the field for the greater part of August and September, the duties of Acting Director have devolved upon me.'

Collections by the staff.

'The following specimens have been collected by or received from officers of the staff, or employees, during the year 1901 :—

Professor Macoun :—

Small collection of snakes and batrachians from south-western Ontario.

Dr. R. W. Ells :—

One hundred and four specimens of fossils from the Trenton limestone at Bear Point, Wolfe island, Ontario.

Hugh Fletcher :—

Fourteen specimens of a graptolite (*Dictyonema Websteri?*) from Silurian slates at Kentville, N.S.

R. J. McConnell :—

Bones and portions of skulls of bison, Rocky Mountain sheep, &c., from the stream gravels on Thistle creek, Yukon territory.

A. P. Low :—

Two specimens of supposed fossils, from island off Long island, ten miles north of Cape Jones, east coast of Hudson Bay.

L. M. Lambe :—

A large collection of remains of dinosaurs, turtles, crocodiles, fishes, primitive mammals, and other vertebrata from the Belly River series of the Red Deer river, Alberta.

W. McInnes :—

Stone adze or scraper from the north side of Lac Seul, Keewatin.

Collections by the staff.

Dr. H. M. Ami :—

About 250 specimens of Trenton and Black River fossils, from the counties of Frontenac, Addington, Prince Edward, Lennox and Hastings, Ont.

Several hundred Pleistocene fossils from various localities in the valleys of the St. Lawrence and Ottawa rivers. Several fragments of pottery from the shore of Lake Ontario, in Prince Edward county.

Twenty specimens of Chazy fossils from Ironsides, P.Q.

R. W. Brock :—

Indian pestle from the north fork of Kettle river, B.C.

D. B. Dowling :—

One hundred and fifty specimens of Silurian fossils from the Equan river, Keewatin.

About twenty-five Pleistocene fossils and twelve fresh water shells from the plateau west of James bay.

Two specimens of mice from the valley of the Equan river.

J. M. Macoun :—

Four hundred and forty-two skins of birds and mammals, and about 300 specimens of fifteen species of reptiles, batrachians, &c., from the Chilliwack river valley, B.C.

W. J. Wilson :—

Twenty-five fossils from the Utica slate at Ottawa.

Fifty-nine arrow heads, adzes, pieces of pottery, &c., from the east end of the portage across the peninsula in Lake Abitibi, five miles east of the outlet of the lake; and a few fresh water shells from that lake.

W. W. Leach :—

Thirty-six fossils (plants, mollusca, corals, &c.) from various localities and formations in the Crows Nest Pass.

R. A. Daly :—

Sixty fossils from the Chilliwack river valley, Coast Range, B.C.

Fifteen specimens of fossil plants from Sumass mountain, B.C.

J. C. Gwillim :—

Twenty-five specimens of fossiliferous rocks from various localities in Atlin, B.C.

H. S. Poole, Stellarton, N.S. :— Collections by the staff.

Fifteen specimens of fish teeth, scales, &c., from roof of coal seam at Mill Brook, Fair View, near Dorchester, N.B.

A. McKinnon :—

Two recent marine sponges (*Desmacidon palmatus*) from Cape Blomidon, N.S.

'The additions to the palæontological, geological and ethnological collections during 1901, from other sources, are as follows :— Collections from other sources.

By presentation :—

(*A.—Palæontology.*)

Mrs. H. A. Nicholson, Aberdeen, Scotland :—

The types of ten species of fossil corals, from the Trenton, Hudson River, Corniferous and Hamilton formations of Ontario, described by the late Professor H. A. Nicholson, with thirteen microscopic sections illustrative of their structure.

Colonel C. C. Grant, Hamilton, Ont. :—

Twenty-five specimens of fossils from the Silurian rocks of Ontario; six from the Niagara chert at Hamilton, and nineteen from the Hudson River drift at Winona, Ont.

Mrs. Hetherington, Cannamore, Ont. :—

Specimen of a fossil coral (*Columnaria Halli*) from the Birdseye and Black river formation on lot 6, concession X, Finch.

W. S. Odell, Ottawa, Ont. :—

Remains of seal from marine Pleistocene clays near Ottawa.

A. R. Wilson, Fernie, B.C. :—

Fine specimen of a fossil plant from Hosmer, B.C.

Rev. G. W. Taylor, Wellington, B.C. :—

Sixty specimens of Cretaceous fossils, some of them new to science, from Brennan creek, near Wellington, V. I.

Dr. C. F. Newcombe, Victoria, B.C. :—

Specimen of *Turrilites Charlottensis*, shewing the septation which was previously unknown; and cast of the interior of the dorsal surface of the test of a heart urchin; both from the Cretaceous rocks of the Queen Charlotte Islands.

Collections from other sources.

T. J. Pollock, Aylmer, P.Q. :—

Small collection of native Pleistocene shells from Aylmer.

W. Milne, Ottawa, Ont. :—

Marine Pleistocene shells from a depth of twenty feet in the main drain, corner of O'Connor and Mutchmor streets, Ottawa.

M. P. Davis, Sillery, P.Q. :—

Root of hemlock (*Tsuga Canadensis*) from Pleistocene gravels at Victoria Cove, Sillery, P.Q.

Captain Constantine, N.W.M.P., Dawson, Y.T. (per G. M. Dawson) :—

Fossil plant from near Nulatto, Yukon river.

A. H. Taylor, Ottawa (per Dr. H. M. Ami) :—

Tooth of mammoth from the Pleistocene of the Yukon valley near Dawson, Y.T., collected by Dr. A. M. Taylor.

J. W. Baldwin, Ottawa, Ont. :—

Specimen of trilobite (*Triarthrus*) from the Utica formation at New Edinburgh.

T. C. Weston, Quebec City, P.Q. :—

Two specimens of an *Orthoceras* from the Black River limestone at Lorette falls.

E. W. Kendall, Ottawa, Ont. :—

Twenty specimens of marine Pleistocene fossils, from seven miles north of Morrisburg, Ont.

E. A. Hoare, Quebec City, P.Q. (per Dr. Ami) :—

Series of cores and other drillings from the bed of the St. Lawrence at Victoria Cove, Sillery, on the site of the foundation of the piers of the Quebec bridge.

Frank Burrows, Joggins Mines, N.S. :—

Two pieces of core of a calyx drill, with fossil plants, from Lynx lake, at head of Lingan Basin, just above the coal, in boring made by Mr. Burrows, July 13, 1901.

Small piece of shale, with *Cordaites*, &c., from Buchanan's seam, supposed to be the same rock as the above.

(B.—*Zoology.*)

Collections from other sources.
Zoological specimens.

Dr. R. Bell, Ottawa :—

One specimen each of the Canadian Porcupine, Laughing Goose, Least Rail, Ptarmigan, Bald Eagle (young), Gyrfalcon and Great Horned Owl, from the west coast of Hudson Bay.

Rev. G. W. Taylor, Wellington, V. I. :—

Twenty-nine marine calcareous sponges and one silicious sponge, from Boat Harbour, six miles south of Nanaimo.

Robert Fox, Maxwell's Lake, P.Q. ; per W. L. Marler :—

Two pairs of the Arctic Three-toed Woodpecker ; one pair each of the Pine Grosbeak, Northern Shrike, and white-bellied Nuthatch ; and one specimen of the Pileated Woodpecker.

S. E. Wilson, Cascades, P.Q. :—

Star-nose Mole (*Condylura cristata*), from the Cascades.

J. E. Keays, London, Ont. :—

Set of three eggs of the Red-shouldered Hawk (*Buteo lineatus*), from near London.

Rev. C. J. Young, Sharbot Lake, Ont. :—

Set of three eggs of the Red-shouldered Hawk, from Leeds Co., Ont.

H. H. Ross, Medicine Hat, Assa. :—

Horned Toad (*Phrynosoma Douglasii*), from Medicine Hat.

Edwin Beaupré, Kingston, Ont. :—

Set of four eggs of the Swamp Sparrow (*Melospiza Georgiana*) with one Cowbird's egg,—from the Cataraqui Marsh near Kingston.

E. J. Chamberlin, Ottawa :—

Fine specimen of head of Moose (mounted) with abnormal antlers.

V. V. Rogers, Ottawa :—

Young loon and fine male Canvas-back Duck (*Aythya vallisneria*), both shot at Stanley Island, St. Lawrence River.

Messrs. McDougall and Secord, Edmonton, N.W.T. ; per the Hon. Clifford Sifton :—

Two skins of the Arctic Fox.

Collections from other sources.

Lawrence W. Watson, Charlottetown, P.E.I.:—

Specimen each of the Black Hare and Grey Hare from Prince Edward Island.

W. M. Antiss, Ottawa:—

Specimen of Brunnich's Murre, shot near Ottawa.

(C.—*Archæology.*)

Archœological specimens.

F. Dunn, Barry's Bay, Ont.; per Dr. A. E. Barlow:—

Four stone implements from Welshmans Island, Barry's Bay, Renfrew Co., Ont.

W. E. Calvert, Ottawa:—

Stone gouge found on Elgin st., near Pattersons Creek, August, 1884.

Mrs. M. Deane-Freeman, McLeod, Alberta:—

Two 'buffalo stones,' very scarce and held in great reverence by the aborigines from the Blood Reservation at Fort McLeod.

ARTESIAN WELLS, PALÆONTOLOGY, ARCHÆOLOGY, BIBLIOGRAPHIES, ETC.

Work by Dr. H. M. Ami.

Dr. H. M. Ami reports as follows:—'During the earlier part of the year much of my time was spent in office work: determining various collections of fossils from different provinces obtained by officers of the staff and others, with a view to ascertaining the precise geological horizon or formation to which they should be assigned.

'Examinations were made of numerous samples of drillings and cores from wells sunk at various localities in Ontario and Quebec. Sections were prepared in some instances from these logs, giving the order of succession of the strata traversed and the geological formations represented. The wells were for the most part bored for petroleum, natural gas, salt or water.

Well at Ramsay's corners.

'From lot 18, con. VII, township of Gloucester, county of Carleton, numerous specimens of the core of a diamond drill in "Well No. 1," near Ramsays Corners, were sent to the department for examination. The Pleistocene formation in the district reached a thickness of 204 feet, while the Lorraine formation, consisting of fine-grained silicious mudstones and shales with here and there a thin calcareous band, was found to be much thicker than shown in any previous records in the department. Notes on the fossils detected in the cores of drillings at different depths were kept and afforded satisfactory evidence upon which to determine the age and position of the strata traversed. Well No. 1 reached a depth of 469 feet, whilst well No. 2, on lot 8, con. V, Rideau front, in the township of Gloucester, was drilled to a depth of 460 feet, and the Utica formation, consisting of black bituminous shales, was satisfactorily recognized. An estimate of the probable thickness of the Palæozoic sediments in this vicinity gave 1,540 feet.

Well four miles east of St. Gregoire.

'Notes on a series of drillings from a deep well on Concession Pointu, four miles east of St. Gregoire, township of Becancour, Que., were recorded, and a section giving the succession of strata at various depths prepared from the materials sent from the well in which it was reported that a bed of salt, fifty feet in thickness occurred. No evidence of the salt rock was found. The drillings consisted, for the most part, of fine-grained red silicious mud, representing the Medina formation, or lowest division of the Silurian system in that district.

Microscopic sections.

'Microscopic sections, numbered 2,211 to 2,215, were prepared from small chips of rock occurring in the drillings sent to the Geological Survey for examination from the depths of 1,632½ and 1,635 feet respectively in the well at Hepworth, Ontario. Dr. Barlow, to whom these micro-sections were submitted, describes the rock as "grit, chloritic and kaolin material, fine-grained limestone or dolomite, and arkose." This rock resembles in character the basal series of strata underlying the Black river formation throughout central Ontario or lying between that formation and the uneven rounded and worn surfaces of the Archæan below.

'During the drilling for water on the property of the Ottawa Produce Company in Nicholas street, in Ottawa city, where the surface rock, only a few feet below the level of the street, consists of the upper beds of the Trenton formation, water rising to the surface was struck in abundance. It was ascertained that the well was put down in a direction in line with the strike of the folded strata which may be seen at the south-western slope and base of Nepean point, Ottawa.'

Assist Dr. Ells.

At the end of July Dr. Ami was instructed to proceed to Kingston and vicinity in order to assist Dr. Ells in determining in the field the age of some of the rocks, from the palæontological evidence, and thirteen days were spent on this work.

Some obscure fossils obtained by Mr. Gwillim at three localities in the Atlin gold district in British Columbia, were examined by Dr. Ami and subsequently by Dr. T. W. Stanton, of the United States Geological Survey, who furnished a few notes on them for Mr. Gwillim's report.

'Amongst the collections obtained during the past season are two specimens of a core of a calyx-drill from Lynx lake at the head of the Lingan basin, just above the coal and 21 feet down in a boring made by Mr. Fraser Burrows. They exhibit three well-known species of fossil plants, characteristic of coal-bearing strata: *Sphenophyllum cuneatum*, *Alethopteris Serlii* and a *Cardiopteris*.

Collections recorded.

'Records of all the additions to the ethnological and archæological collections have been made and the specimens catalogued. Records of additions to the palæontological collections in the Museum were also kept, as well as a list of additions to the series of sections for the microscope. Amongst the latter is a series of foraminifera, &c., from boulder clays (glacial?) collected by Dr. Dawson and other officers of the Survey in different portions of Canada. These minute organisms are of value in ascertaining the origin of the boulder clays of the North-west Territories. They were mounted by Joseph Wright, Esq., of 4 Alfred St., Belfast, Ireland, to whom the department is under special obligations for their determination and identification.

'Micro-sections of Prof. D. P. Penhallow's new species of larch from the Churchbridge well, Manitoba, at the depth of 200 feet in the Pleistocene of that province, were received and recorded. The specimens from which this species was described were collected by Messrs. J. B. Tyrrell and G. H. Webster in 1892.

Loan of specimens.

'As mentioned in last year's Summary, through the kindness of the authorities of the American Museum of Natural History, New York city, this Department has been lent, in order to study and re-figure, if necessary, the original types of certain species of Silurian fossils from the Arisaig coast of Antigonish, Nova Scotia. The first consignment of these fossils has been studied and drawn preparatory to their return to the Central Park Museum. The examination of these types throws much light upon difficult questions in nomenclature and classification which have arisen in the study of Silurian faunas from Stonehouse, Moydart, McAdam and Arisaig. From the light yellow or buff weathering fossiliferous sandstones, &c., of the Arisaig rocks, as described on page 180 of the Summary Report for 1900, the 'interstratified bands of shale,' &c., mentioned, must be eliminated from the arenaceous series. These strata are highly disturbed and may constitute a separate or distinct series whose relations and age require to be examined more critically before a definite conclusion may be reached.

'Further studies have been made on additional specimens of the genus *Dictyonema* from different localities in Nova Scotia and New Brunswick. Specimens of *Dictyonema Websteri* from the highly inclined and cleaved red and green shales of King's county, Nova Scotia, have also been studied and notes made upon them.

'Synopses of Canadian palæontological publications have been prepared for the 'Geologische Centralblatt,' at the request of Dr. K. Keilhack, Director of the Geological Survey of Germany, &c., and in accordance with instructions received from the late Dr. G. M. Dawson.

Survey's collections in Peter Redpath Museum.

'At the time of Sir J. W. Dawson's death, a number of collections of fossil plants were in his hands and these are now awaiting determination in the Peter Redpath Museum. These collections are as follows: Fossil leaves and other plant remains from the Red Deer and Blind Man rivers; fossil plants from Port McNeil, British Columbia; fossil plants from various localities in the Queen Charlotte Islands; plant remains from Lytton, B.C., collected by the late Dr. G. M. Dawson; specimens of fossil ferns from Skidegate Inlet, Queen Charlotte Islands, collected by the late Dr. G. M. Dawson and recently described in MS. by Prof. Penhallow as a species of *Osmundites*.

Fossils donated.

'During the past year, a small collection of fossils was selected and sent to the Museum of King's College, Windsor, Nova Scotia, from amongst the duplicate specimens in the Museum, and a collection of about 150 specimens of fossils from the geological formations of the Ottawa district was determined and sent to Prof. H. S. Poole, of Dalhousie University, Halifax, N.S.

In the same period the following papers were published:—

Papers published.

'Preliminary lists of the organic remains occurring in the various geological formations comprised in the map of the Ottawa district, including portions of provinces of Qnebec and Ontario, along the Ottawa river.' Published as an appendix to Dr. Ells' report on the Geology of the Ottawa City map.

'Preliminary lists of the organic remains occurrring within the area comprised in the Grenville map sheet.' Prepared as an appendix to Dr. Ells' Report.

'On the Geology of the Principal Cities in Eastern Canada.' containing descriptions of the various systems, formations, characteristics fossils, etc., arranged in tabular form for the cities of

St. John, Quebec, Montreal, Ottawa and Toronto. Trans. Royal Society of Canada, 2nd series, Vol. 6, Sec. IV, pp. 125–173.

'On a new or hitherto unrecognized geological formation in the Devonian system of Canada.' Published in the Canadian Record of Science, Vol. 8, No. 5, pp. 296–305, January, 1901.

'Knoydart Formation of Nova Scotia.' (Read before the Geological Society of America, Albany, N.Y.) Published in Bull. Geological Society America, Vol. 12, pp. 301–312, Pl. 26, August, 1901, Rochester, N.Y.

'Description of new tracks or trails made by some fish-like organism from the fine-grained silicious mudstones of Antigonish county, Nova Scotia.' Read before the Nova Scotia Institute of Science, May 13, 1901, and printed in Proc. and Trans. Nova Scotia Inst. Sc., Halifax. (Session 1900–1901.)

'Stratigraphical Note,' containing subdivisions of the Devonian and Silurian of the Arisaig region of Nova Scotia. Published in Science, new series, Vol. 13, No. 323, pp. 394–395, March, 1901.

'Notice of Prof. E. D. Cope's article on Cyphornis, an extinct genus of birds.' Published in Canadian Record of Science, Vol. 8, No. 5, pp. 331–332, January, 1901, Montreal.

'Brief Biographical Sketch of Elkanah Billings,' Palæontologist to the Geological Survey of Canada from 1856–1876. Published in the American Geologist, Vol. 27, No. 5, pp. 265–281, May, 1901, Minneapolis, Minn.

'A biographical sketch of George Mercer Dawson.' Published in the Ottawa Naturalist, Vol. 15, No. 2, pp. 43–52, May, 1901, followed by 'Bibliography of Dr. George M. Dawson,' Vol. 15, No. 9, pp. 201–213, December, 1901.

'Besides the above, part of the manuscript of a list of the fossils of the Grand Manitoulin and adjoining islands has been prepared. This report is the result of a study of the palæontological literature of these islands and includes determinations by the late E. Billings, J. J. Bigsby, G. Stokes, Baron de Castelnau, the writer and others. When completed it will form an appendix to Dr. R. Bell's report on the Geology of the Manitoulin Islands now in course of preparation.

Mining Institute.

'At the March meeting of the 'Canadian Mining Institute,' held in Montreal, the following paper was read: 'On the succession and thickness of the geological formations in the gas and oil-fields of Ontario.' The subject-matter in this paper is being embodied in a report for the Department on the gas and oil wells of Ontario and Quebec. At the same meeting, at the request of the executive of the Mining Institute, I prepared and read a biographical notice of the late Dr. G. M. Dawson. A Bibliography of Canadian Geology and Palæontology during the year 1900, was prepared for the Transactions of the Royal Society of Canada. I have also supervised the preparation of the manuscript of the Index to Canadian Geology and Palæontology from my card catalogue of the Bibliography of Canadian Geology, &c. The bibliographies of the following writers have already been prepared :— Sir William E. Logan, Sir Richard Owen, Sir J. William Dawson, Dr. T. Sterry Hunt, Elkanah Billings, C. Fred Hartt, L. W. Bailey, S. H. Scudder, Dr. G. M. Dawson, H. M. Ami.

Pleistocene geology and artesian wells.

Dr. Ami having already paid some attention to the Pleistocene geology of the province of Quebec and the valley of the Ottawa river, and also to the collecting of logs of artesian wells, he was given the following instructions. Shortly after receiving them, however, he was sent, at the request of Dr. Ells (as mentioned on a previous page) to assist him palæontologically in his work in the district around Kingston. Thirteen days of his time were devoted to that work.

In order to do thoroughly the Pleistocene geology of the areas mentioned in Dr. Ami's instructions, the time of one man for more than a single season might be profitably spent and it was explained to him verbally that he would only be expected to do what he could to obtain as much new information as possible to add to what we already knew of this interesting subject in the region west of the city of Quebec, described in his instructions.

INSTRUCTIONS.

OTTAWA, July 13, 1901.

Instructions.

DEAR DR. AMI.—In the month of April, I mentionned to you that I wished you to make certain original investigations in the field in two departments of geology which I knew were congenial to your taste and inclination, viz: (1) in connection with the pleistocene geology of part of the province of Quebec and part of the Ottawa valley, and (2) to collect in the same regions the records of artesian wells bored into the solid rocks in search of water, etc.

The general nature and the main divisions of the superficial deposits of the province of Quebec are described in the Geology of Canada, 1863. Since that time geologists have been paying much attention to pleistocene geology and it has now become very desirable that we should make a more systematic and complete investigation of these deposits than has hitherto been attempted.

Instructions to Dr. Ami.

For this purpose, I wish you to work in the field during the present season on this subject and that of the artesian wells referred to. The territory you are to examine extends from the city of Quebec up the River St. Lawrence to Lake St. Francis (where the boundary of Ontario comes to the water) and on either side of the river as far as the high lands which limit the area of the Saxicava sands to the north-east and the south-west. Try to map out in more detail than has heretofore been done, the geographical distribution of this formation and also of the underlying Leda clay. Also try to ascertain the thickness of each formation at as many localities as possible. Visit such localities as you may think likely to prove of particular interest, as to these or other superficial formations and make such investigations as will enable you to describe correctly the phenomena observed. Note the names of all the species wherever you may observe the occurrence of organic remains in any of the surface deposits.

Your work in the Ottawa valley will extend from the mouth of the river as far west as Mattawa and will be mainly on the south side, extending to the general line of the height of land of the St Lawrence. Here the Leda clay and Saxicava sand will also claim your attention with the same objects as in the St. Lawrence valley. The work you have already done in this district, especially in connection with the organic remains at Green's Creek, etc., will be of much service to enable you to prepare as full a report as possible on the whole subject.

In both the St. Lawrence and Ottawa regions you will also investigate ancient glacial phenomena and all the evidence connected with moraines, boulders, drumlins, kames, osars, sand or gravel plains, old or new land slides, ancient potholes, etc.

Wherever you find distinct evidence of ancient shore lines, take their altitude above the sea or some well-established bench-mark, or water level. As to boulders, note the general size prevailing at any given place, whether angular, sub-angular or rounded, composition or character, how grouped or arranged or occurring.

Note what has been ascertained by experience as to the value or otherwise of clays in different places for the manufacture of brick, pottery, tiles, etc.

Ascertain as much as possible as to peat—the areas, position of boundaries all around the bog, depth, quantity, former attempts to manufacture or use, reasons of failure, suggestions for further trials, etc.

Particulars should be noted as to shell-marl, infusorial earth, ochre, bog iron, sand for moulding, glass-making and any other substance that may be of value.

Collect as much information as possible in regard to springs, wells and underground waters generally among the superficial deposits.

(2.) *Artesian wells.*

As to this second division of your work, try to ascertain where any artesian well has been or is being bored. In each case obtain the best possible 'log,' together with samples of the cores or drillings. Where no regular or systematic 'log' of the well has been preserved, try to ascertain any facts you can about it from the most reliable source, such as date of boring, by whom bored, total depth, general character or rocks penetrated, or any peculiarity connected with them, such as the quantity of water obtained, whether saline, bitter, hard, soft, etc. Inquire as to any indications of gas or petroleum.

The above will provide an ample field and amount of work for your energies for one season without going to Gaspé, about which you spoke. I expect to be able to obtain 'logs' of the wells which have been bored in this district from another source and you will therefore not proceed to that part of the province.

Yours faithfully,

ROBERT BELL,
Acting Director.

H. M. Ami, Esq., F.R.S.C., &c.,
Geological Survey,
Ottawa.

ENTOMOLOGY.

Dr. James Fletcher.

Report of the Entomologist.

Dr. James Fletcher, Entomologist and Botanist to the Dominion Experimental Farms, as Honorary Curator of the entomological collection in the museum of this Department, furnishes the following report:—

I have the honour to report that the entomological collections are all in good condition. A few additions have been made, mainly from my own collection. The most important of these is a specimen of the very rare *Erebia Vidleri*, Elwes. Three specimens of this butterfly were discovered over thirty years ago somewhere in the mountains of British Columbia by a Capt. Vidler, but nothing was known as to the locality and date. In 1898, on August 15, I was fortunate enough to rediscover the species on Mount Ché-am, near to Agassiz, in the valley of the Fraser. Three specimens were taken, one of which I have had pleasure in depositing in the National Museum. Very few additions have come from the collections made by the field staff of the Geological Survey.

Collections received.

1. I have received one small collection made by Mr. William McInnes around the Lake of the Woods in the autumn of 1899. These were chiefly lepidoptera which had been already recorded from that district.

2. A small but exceedingly interesting collection was handed to me by Prof. John Macoun for naming, made on Telon river in June and July, 1900. These specimens bore on the labels 'J. L.' but Prof. Macoun tells me that they were collected by Mr. Jas. Tyrrell In this collection I found one specimen of the rare Arctic butterfly *Erebia Rossi*, Kirby, of which previously we had no specimen in the collection. There were other species in this collection which will be of use for the cabinets, but which were in rather poor condition.

3. A collection of lepidoptera, coleoptera and neuroptera, was made by Mr. James Macoun in June, July and August, 1901, along the Chilliwack river and at Sumass lake, in British Columbia. In this collection was one much damaged specimen of the rare *Erebia Vidleri*, above referred to, taken at 6,000 feet elevation in the Ché-am mountains. These are the only localities so far known for this insect. Among the beetles, the best addition to the museum was *Pachyta armata*, Lec., a rare and handsome carambycid.

Utility of collecting.

May I again ask you to urge upon the members of the staff the value to the museum of collections of insects, however small these may be, when exact dates and localities are given. As I have pointed out previously, if each party would bring back only half a dozen specimens, there would doubtless be included in these every year valuable additions to the national collection. Every specimen placed in the cabinets bears the collector's name and the locality and date of capture. Full credit is also given every year in the report, and complete lists are kept with the idea at some future time of publishing a systematic catalogue of the insects of Canada, similar to Prof. Macoun's invaluable catalogues of plants and birds.

I am quite aware that the officers of the Geological Survey have a great deal to do when in the field and that they have not many facilities for collecting and caring for such delicate specimens as insects, but their opportunities are so exceptional and such good work has already been done by a few, such as yourself, Dr. Geo. Dawson, Messrs. John and J. M. Macoun, W. McInnes, A. P. Low and J. McEvoy, that in the hope of inducing others to do work of a similar nature I beg to request you to ask all members of the Geological Survey staff working in the field in new localities to make an effort to bring home with them at least a few specimens every year. No matter what these may be, there is sure to be something among them that is desirable, and which will add, not only to the museum collection, but to the known facts with regard to many species of economic and scientific importance. I would specially request that attention be paid to the insects which injure forest trees, and, in conclusion, I would point out that great care should be taken in labelling every specimen with the locality and the date of capture. Lepidoptera, neuroptera and hymenoptera may be placed in envelopes, one specimen in each; specimens of orthoptera should each be rolled in paper, and coleoptera may be placed in bottles among sawdust slightly dampened with alcohol. The label for these should be written in pencil on paper and placed inside the bottle with the specimens.

Exceptional opportunities.

Insects injurious to trees.

THE LIBRARY.

Dr. John Thorburn.

During the ten months from January 2, to October 31, 1901, there have been distributed 8,305 publications of the Geological Survey, comprising reports, parts of reports, special reports and maps. Of these 4,364 were distributed in Canada; the remainder, 3,941, were sent to foreign countries as exchanges to universities, scientific and literary institutions and to a number of individuals engaged in scientific pursuits. Due care has been exercised in the distribution of our publications, inasmuch as if all the applications were granted, the supply which is limited would soon be exhausted. A large number of the earlier reports and maps are now out of print, and can no longer be supplied.

Distribution of publications.

The sales of publications during the above period, including reports and maps numbered 3,117; the amount received for those being $530.45.

There were received, as donations or exchanges 2,427 publications, including reports, transactions, proceedings, memoirs, periodicals,

Donations received.

pamphlets and maps; besides which twenty-seven publications were purchased and thirty-seven scientific periodicals were subscribed for.

The number of volumes bound was 120.

Letters.

The letters received in connection with the library numbered 967, besides 744 acknowledgments for publications sent out.

The number of letters sent out from the library was 969, besides 521 acknowledgments for exchanges and to persons from whom publications were received.

Volumes in library.

There are now in the library by actual count 12,706 volumes, besides a large and valuable collection of pamphlets.

As has been frequently stated in former reports, the space available for library purposes is altogether insufficient. The cases are filled and a large number of books are piled up on the floor of the library and in other parts of the building, and consequently, it is often difficult to find books which are required for consultation by members of the staff.

It may be stated that books in the library are available for consultation by persons wishing to obtain information in regard to any scientific subject.

VISITORS TO THE MUSEUM.

Visitors to the Museum.

The number of visitors to the museum who signed their names, was 37,895 during the calendar year 1901, being an increase of 1,804 over the previous year, but a large percentage of the visitors do not take the trouble to register.

STAFF, APPROPRIATION, EXPENDITURE AND CORRESPONDENCE.

Staff, etc.

The strength of the staff at present employed is fifty-four.

During the year changes in the staff have taken place by the death of Dr. G. M. Dawson, Deputy Head and Director, and by the resignation of Messrs. J. C. Gwillim, A. P. Low and James McEvoy.

Messrs. W. W. Leach and Jos. Keele, science graduates, were appointed to the positions rendered vacant by Messrs. McEvoy and Gwillim.

The funds available for the work and the expenditure of the department during the fiscal year ending June 30, 1901, were:—

Details.	Grant.	Expend'ure.
	$ cts.	$ cts.
Civil-list appropriation	53,900 00	
Geological Survey appropriation	62,000 00	
Civil-list salaries		51,436 14
Exploration and survey		21,724 86
Wages of temporary employees		16,952 32
Printing and lithography		13,276 84
Purchase of books and instruments		1,307 58
" chemical apparatus		133 38
" specimens		91 60
Stationery, mapping materials and King's Printer		1,459 19
Incidental and other expenses		2,299 26
Advances to explorers on account of 1901-02		14,234 27
		122,915 44
Deduct, paid in 1899-1900 on account of 1900-01		9,537 80
		113,377 64
Unexpended balance civil-list appropriation		2,463 86
" " survey "		58 50
	115,900 00	115,900 00

The correspondence of the department shows a total of 6,822 letters sent, and 7,110 received.

I have the honour to be, Sir,
Your obedient servant,

ROBERT BELL,
Acting Deputy Head and Director.

DAWSON CITY.

[*Frontispiece.*]

GEOLOGICAL SURVEY OF CANADA
ROBERT BELL, M.D., D.Sc. (CANTAB.), LL.D., F.R.S.

REPORT

ON THE

KLONDIKE GOLD FIELDS

BY

R. G. McCONNELL, B.A.

OTTAWA
PRINTED BY S. E. DAWSON, PRINTER TO THE KING'S MOST
EXCELLENT MAJESTY
1905

14—B

No. 884

Dr. R. Bell, F.R.S., &c., &c.
Acting Director Geological Survey
Ottawa:

Sir,—I beg to submit the following Report on the Klondike Gold Fields based on field work carried on during the season of 1903. A preliminary report on this district was published in 1900, portions of which are incorporated in the present one.

I have the honour to be, Sir,
Your obedient servant,
R. G. McCONNELL.

Geological Survey Office,
May 15, 1904.

REPORT

ON THE

KLONDIKE GOLD FIELDS

BY

R. G. McCONNELL, B.A.

HISTORICAL.

An account of the early gold discoveries in the Upper Yukon is given by Dr. Dawson in the Report of the Geological Survey for 1887-88 pages 178-183 B and also by Mr. Goodrich in the Eighteenth Annual Report of the United States Geological Survey, 1896-97, part III, pages 103-124 and need not be repeated here at length. Briefly, the existence of gold on the Yukon has been known since 1869, at least. The first prospector entered the country, according to Dawson, in 1878, and to Goodrich, in 1873. Bar-mining commenced on the Big Salmon in 1881 and discoveries of productive bars on the Lewes Pelly and Stewart soon followed. The latter stream proved the more productive and in 1885-86 was actively worked. The first discovery of coarse gold was announced in 1886. The discovery was made on Fortymile river and the greater part of the new field proved to be in Alaskan Territory. Further discoveries extended the producing area to streams flowing into Sixtymile river in Canadian Territory. The Sixtymile river streams continued to be the chief producers, until the announcement in 1896 of the discovery of astonishingly rich creeks in the Klondike district drew most of the miners away. Discovery.

Although the Klondike district did not become prominent until 1896, it was really discovered two years earlier. In 1894 some miners working on the bars on Indian river did some prospecting on Quartz creek and in the following year some gold was taken out. Reports differ as to who made the first discovery on Quartz creek, several persons claiming the honour. In the winter of 1895, Bob Henderson crossed the ridge separating Quartz from Hunker creek and found gold on Goldbottom creek, a tributary of the latter. He did some work on

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NOTE.—Mr. R. G. McConnell has been engaged in work in the Klondike district in 1898, 1899 and 1900. In 1899 and 1900 he was assisted by Mr. J. F. E. Johnston, who had charge of the topographical work. The topographical map accompanying this report has been constructed by Mr. Johnston from surveys largely made by himself.—R. B.

this creek in 1896, and it was while returning from a visit to him that Carmack made his famous discovery on Bonanza creek, which led to the rapid over-running of the whole district. In 1897-98 a stream of adventurers, including people of all trades and callings, from all parts of the world, poured into the country, all heading for the Klondike. The population of the camp rose to about 30,000 and the production increased rapidly, reaching a maximum in 1900, when it exceeded twenty-two millions of dollars.

Changed conditions.

The discovery of the Klondike gold fields completely changed conditions in the hitherto unorganized and almost unknown Yukon Territory. The town of Dawson was built at the confluence of the Yukon and Klondike rivers and sprang rapidly into importance, soon superseding Fortymile as the chief commercial centre. A local administration, with courts of Justice and other organizations necessary to government, were quickly established. The demand for better transportation was met by the construction of the White Pass railroad from tidewater at the head of Lynn canal to the foot of the White Horse rapids on the Lewes river, from which point communication with Dawson is maintained by a large fleet of well-equipped river steamers. At the present time the trip from Vancouver to Dawson can be made in comfort in less than a week. Other notable improvements in the condition of the camp consist in the establishment of telegraphic communication with the outside world and in the construction by the Government of a system of roads from Dawson up all the producing creeks. These roads have proved a great boon to the camp, as the excessive rates of early days, now that freight can be moved on wheels, have been reduced to reasonable figures, and comparatively low-grade gravels on the distant creeks can be worked at a profit.

EXTENT AND SITUATION OF THE KLONDIKE GOLD FIELDS.

Area.

The Klondike gold fields are situated east of the Yukon river in latitude 60° north. They are bounded in a general way by the Yukon river on the west, by the Klondike river on the north, by Flat creek, a tributary of the Klondike, and Dominion creek, a tributary of Indian river, on the east, and by Indian river on the south. The area included between these boundaries measures about 800 square miles. The streams flowing through the area described are all gold-bearing to some extent, but only a limited number have proved remunerative. The most productive streams are Bonanza creek, with its famous tributary Eldorado creek, Bear creek and Hunker creek flowing into the

Klondike, and Quartz creek and Dominion creek with Gold-run and Sulphur creek, two tributaries of the latter, flowing into Indian river. Besides these, claims have been worked at a profit on Allgold creek, a tributary of Flat creek, and on Eureka, a tributary of Indian river from the south.

TOPOGRAPHY.

GENERAL SURFACE FEATURES.

Plateau character.

The Klondike region is a typical example of the thoroughly dissected upland. It forms part of the Yukon plateau and old peneplain, elevated at one period in its history into a high plateau and subsequently deeply trenched by a multitude of small streams, tributary to the main water courses. In comparatively recent times, a second elevatory movement has taken place, resulting in a further deepening of the valleys of from 500 feet to 700 feet. Portions of the old valley-bottoms, still covered with heavy accumulations of gravel, occur at many points, forming terraces of varying width, bordering the newer valleys.

Viewed from a distance, the Klondike district has a hilly, even montainous aspect, but in reality consists of a series of long branching ridges, the summits of which have been carved irregularly into hill and hollow by unequal denudation. Most of the ridges originate at or near the Dome, the topographic centre of the district, and the highest eminence in it.

The Dome.

The Dome is situated nineteen miles south-east of Dawson, about midway between Indian river and the Klondike. It has a height of about 4,250 feet above the sea, 3,050 feet above the Yukon at Dawson and about 500 feet above the ridges at the base. It is not conspicuously higher than the other hills in the neighbourhood, and the gradual decrease in height outwards along the ridges radiating from it, is scarcely noticeable to the eye. The Dome is the principal drainage centre of the district. From it, Allgold and Dominion creeks flow eastward, Quartz and Sulphur creeks southward, and Goldbottom and Hunker creeks northward. The ridges separating these streams, although deeply and repeatedly gashed by tributary valleys, are unbroken, and it is possible, starting from the Dome, to reach any part of the district without descending into the valleys. Subordinate drainage centres occur between the sources of Ensley and Nine-mile creek, of Baker and Boulder creeks, and at other places.

Ridges.

The ridges have an average elevation above the valley-bottoms of 1,500 feet and above the sea of 3,200 feet. They are round backed, branching elevations with slopes of from 10° to 20°. The crest line usually follows a zigzag course along the heads of tributary valleys and is broken, at intervals, by rounded prominences and bare rocky points.

Valleys.

The valleys are flat and wide in their lower reaches, but gradually narrow towards their heads into steep-sided narrow gulches, which terminate abruptly in steep, rounded, cirque-like depressions cut into the sides of the ridges. The valley-flats are marshy, partly wooded, and wider on the Indian river than on the Klondike slope. The flats bordering the lower parts of Dominion creek have a width in places of nearly half a mile.

Terraces.

The lower slopes of the valleys are often conspicuously terraced. Well-marked rock-cut benches, usually supporting beds of gravel, occur along the Yukon and Klondike rivers and extend for varying distances up most of the creeks. The principal rock bench has an elevation near Dawson of about 300 feet above the Yukon or 1,500 feet above the sea, while smaller terraces and rolled gravels, occur up to a height of 700 feet above the valley-bottoms. The main terrace decreases in height ascending the Yukon and disappears near the mouth of the Stewart. It increases in height down stream as far as the mouth of Forty-mile river, where it has an elevation of about 700 feet above the valley-bottom.

Ice.

The Klondike district has not been overridden by ice and the surface rocks, as is usual in unglaciated regions, are deeply weathered. A thick covering of decomposed schist, usually intermingled with slide rock, mantles the side hills nearly everywhere. On the ridges the covering is less, and the schists, often worn into fantastic shapes, occasionally project above the surface, or outcrop along the sides of the steeper hills.

Frost.

Another feature which, although not especially connected with the topography, may be referred to here, is the permanently frozen condition of the surface. The thickness of the frozen stratum varies considerably, and is less on the ridges than in the valleys, and on southern than on northern exposures. A shaft sunk on the ridge south of Eldorado creek reached unfrozen ground at a depth of 60 feet, while one in the valley of Eldorado creek was stopped by running water at a depth of a little over 200 feet. Another shaft sunk through gravel, on the plateau between Bonanza creek and the Klondike river, passed through the frost line at a depth of 175 feet.

The summer heat has little effect on the frozen layer except in the few places where the surface is unprotected by moss. Exposed gravel beds in favourable positions thaw out to a depth of from six to ten feet, but where moss is present, frost is always encountered close to the surface.

RIVERS AND STREAMS.

Drainage.

The drainage of the region empties into the Yukon. This great stream flows past the district with a width of over four hundred yards. It divides around numerous low-wooded islands and shifting bars, and runs with a steady current of about five miles an hour. Its valley is comparatively narrow, with few flats, and the river, sweeping from bank to bank in easy curves, washes alternately the bases of the hills on either side.

Main streams

The Klondike and Indian rivers, which border the district on the north and south respectively, are comparatively small streams. Indian river, formed by the junction of the Dominion and Australia streams, has a width of from twenty to thirty yards but is quite shallow, the water on the bars at summer line seldom exceeding a few inches in depth. The channel is filled, for a long distance below Quartz creek, with large angular blocks of schist, and the navigation of the stream, even with small boats, is difficult. The grade of the valley averages about eighteen feet to the mile. The Klondike is a much larger stream, having a width of from 30 to 50 yards. It is interrupted by frequent bars and has a fall of from 12 to 15 feet to the mile. The average flow at mean level is about 120,000 cubic feet per minute. Both streams are inclosed in wide flat-bottomed valleys.

Smaller streams.

The streams draining the interior of the district are small, seldom exceeding fifteen feet in width, even near their mouths, and are very similar in general character. They rise in a multitude of small branches high up on the sides of the ridges and descend rapidly for the first few miles. Farther down, the inclination gradually diminishes and in the lower reaches is usually very small. The grade of Dominion and other Indian river streams does not exceed twenty-five feet to the mile, near their mouths. The Klondike streams are somewhat steeper, falling about forty feet to the mile.

The cutting down of the forest which covered the hillsides before mining operations began, and the burning away of a portion of the moss has had considerable effect on the drainage. The snow, as a consequence of this, melts more rapidly and spring floods result, while, later in the season, the supply of water is often insufficient for sluicing purposes. Schemes to impound the spring flood in the upper unproductive portions of the valleys have been proposed, but nothing has been done so far in this direction.

FOREST.

Forest trees.

The forest trees consist of white and black spruces, the aspen and and balsam poplars and a species of birch. No pine or fir trees were noticed. The lower ridges and the slopes of the higher ones up to a height of 3,500 feet above the sea are generally wooded, and stunted spruces occur sparingly on the highest points in the district, The flat valleys are only partly wooded. Groves of spruce and poplar occur at intervals, but alternate with bare swamps and marshes too soft to support a forest growth.

The white spruce is the most important tree for general purposes in the district. It is usually small on the ridges, seldom exceeding a foot in diameter, but in the valley-flats occasional specimens attain a diameter of over two feet, and a large proportion of the logs cut for lumber measure from nine to fifteen inches across. The supply for the mills at Dawson is mostly obtained from the flats and islands along the Upper Yukon and from the Klondike valley, and is ample for all purposes for many years to come. The Klondike is bordered at intervals all the way from its mouth to the mountains by groves and small tracts of spruce forest of surprising size and quality, considering the latitude, and supplies of well-grown spruce timber are also available from all the large tributaries of the Upper Yukon, as well as from the main valley, and can be easily and cheaply floated down to Dawson.

GEOLOGY*.

GENERAL STATEMENT.

Alteration of rocks.

The Klondike district and adjoining region is underlaid by a complex of rock formations ranging in age through the greater part of the geological scale and presenting extreme variety in structure and composition. The region has been repeatedly broken through by igneous intrusions at widely separated periods, and has been subjected to enormous presure from earth movements. Alterations in the character of the rocks induced by dynamic and associated metamorphic agencies have proceeded to an extreme degree. Massive igneous rocks have been sheared, granulated and crushed into finely foliated schists, and the clastics in many cases recrystallized into the semblance of igneous rocks.

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* I am indebted to Dr. A. E. Barlow for detailed petrographical descriptions of the large suite of specimens collected as representative of the various rock types and formations noticed in the present report. This work has been fully quoted throughout that portion of this report relating to the geology and lithology.

The oldest and most important formations in the Klondike district consist of ancient schists, partly of clastic and partly of igneous origin.

Schists.

The southern part of the district is underlaid by altered sedimentary rocks now represented largely by grayish and dark quartz mica-schists and crystalline limestones. These are bordered on the north by a wide band of light-coloured, in places almost white, sericite schists alternating occasionally with greenish chloritic schists. These schists have been derived from igneous, and largely from massive igneous rocks. All the principal producing creeks occur in the area occupied by them. The sericite schists and associated rocks are replaced near the mouth of the Klondike river by green diabase rocks usually schistose but in places almost massive. They are everywhere greatly altered and, in Moosehide mountain, pass into serpentines. East of the diabase and serpentine area of Moosehide mountain the sericite schists alternate on the north with bands of dark quartz mica-schists, very similar to those bordering them on the south.

Intrusives.

The old schist floor of the district is penetrated at numerous points by intrusives belonging to several groups. A massive coarse-grained grayish granite, resembling the coast granites, cuts the sedimentary schists on the Yukon river below Indian river. Serpentines, derived in part, at least, from peridotites, occur at several points on the crest of the ridge separating Hunker creek from the Klondike, and numerous small, usually oblong, areas of comparatively recent quartz porphyrites, rhyolites and andesites are dotted irregularly throughout the district. Massive diabases occur on Indian river below New Zealand creek, and in dikes in the Yukon valley opposite Indian river and on Eldorado creek. Unaltered sedimentary rocks, consisting of clays, shales, sands, sandstones, tuffs and conglomerates nearly destitute of determinable fossils, but probably Tertiary in age, overlie the schists in the lower part of the valley of Last Chance creek, and in separated depressions at several points around the outskirts of the district. They occur on the Klondike above Rock creek, on Indian river opposite the mouth of Quartz creek, and the apex of a wide area crosses the Yukon valley below the mouth of Indian river. These recent sedimentary rocks are associated in every area with dikes, stocks, and sheets of andesite and, occasionally, with dikes and small areas of diabase.

The rocks of the district have been separated for purposes of description into the following groups :

Schists—Nasina series, Klondike series, Moosehide diabase.

Unaltered sedimentary rocks—Early Tertiary (Renai?), Late Tertiary (Flat creek beds).

Massive igneous rocks—Granite, diabase, andesites, quartz porphyries, serpentine.

NASINA SERIES.

Altered sedimentary rocks.

Under this head are included the old altered sedimentary rocks of the district. These rocks have been described under various names. They were first studied by Mr. J. E. Spurr of the United States Geological Survey in the Fortymile district north-west of Dawson in 1897. Mr. Spurr, in his excellent and detailed description of the formation, separated it into two divisions, the lower of which he called the Birch Creek series, and the upper the Fortymile series.

Nomenclature.

The prevalence of marbles in the upper series is given as the principal reason for the division. In other parts of the Territory where the formation has since been studied this distinction fails and it has been found impossible to apply Spurr's two names with any accuracy. In 1898 Mr. Brooks described what are evidently the same rocks on White river under the name of the Nasina series, and in 1899 the writer named them, from their occurrence on Indian river, the Indian River series. Subsequently, the Indian River rocks were traced into the Fortymile district and found to be an easterly extension of the clastic series described by Spurr, but whether of the upper or lower division could not be determined. The name Kotlo series was proposed by Brooks in 1899 as a general designation for all the old altered clastics of the Yukon Territory and Alaska. A term of this kind, embracing a number of similar formations, is useful in the early study of a district but must eventually be superseded by more specific names. The name Nasina series has priority over Indian River series and has been adopted by the writer in preference to the two older names proposed by Spurr, as the minerological distinction on which these are based is apparently not persistent.

Composition of Nasina series.

General character.—The Nasina series consists essentially of ancient siliceous and argillaceous sediments now altered into quartzites and quartz mica-schists. These are associated in places with bands of green chlorite and actinolite schists beds and bands of crystalline limestone. The green schists represent, in most cases, basic irruptive rocks, principally diabases and diorites intruded along the bedding planes of the older formation, and subsequently sheared and altered. The limestone beds formed part of the original deposit.

While the rocks of this series are everywhere altered there is a marked difference in the degree of alteration. In the least altered portions the constitutents have a parallel arrangement, and micas and other minerals have been developed, but the original quartz grains are practically unchanged. In the most altered portions, the rocks have been completely recrystallized into fine-grained gneisses difficult to distingush from certain phases of the sheared granitic rocks of the district. The principal field evidence of their clastic origin is afforded by their rapid alternation with quartzites and limestones and their gradual passage in places into the former. With the miscroscope, different stages in the recrystallization process can be detected. The clastic gneisses in some of the sections underlie the less altered quartz mica-schists and may therefore be much older, but as no uncomformity or abrupt change in character was observed, they have been grouped together for the present.

Outcrops,

Distribution.—The rocks assigned to the Nasina series outcrop at intervals along the Yukon valley from a point a few miles below Selkirk down to Fortymile river, and are also found on various tributaries of the Yukon, entering it both from the east and west. They occur in bands, from a few feet to several miles in width, separated, as a rule, by areas of granite gneiss* (Pelly gneiss). They are cut irregularly by the latter. The sections are, on this account, fragmentary and neither the top or bottom of the formation has so far been satisfactorily defined. In the Klondike district, the rocks of the Nasina series are exposed along the Yukon river from a point two miles below Ensley creek up to Indian river, and for some distance beyond. They were traced from the Yukon in a south-easterly direction up Indian river to Ruby creek where they disappear beneath Tertiary sandstone and conglomerates. They come to the surface again west of Eureka creek, and continue to the boundary of the district. On the Yukon, the continuity of the section is interrupted by a granite area and also by an andesite flow of moderate width. Besides the main occurrence of Nasina schists along the southern edge of the district, numerous small irregular patches of precisely similar rocks, often only a few feet in width, occur with the sericite schists of the Klondike series. One of these, on Dominion creek, has been mapped approximately but most of them are too small to show on the scale adopted.

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*Granite gneisses are extensively distributed in numerous areas along the Yukon valley and adjacent regions from the mouth of the Pelly river down to Fortymile river. The name 'Pelly gneisses' has been proposed for them by Brooks. They are described by Spurr under the name of the Basal granites, in the Eighteenth Annual Report of the United States Geological Survey, Part III, pp. 134-137; by Brooks in the Twentieth Annual Report of the United States Geological Survey, Part VII, pp. 460-463; and by the writer in the American Geologist Vol. XXX, July, 1902.

An irregular area of dark and gray quartz mica-schists interbanded with green chloritic schists, occurs on the lower part of the Klondike river bordering the Klondike series on the north. In a preliminary report on the district, published in 1900, these were separated as the Hunker series, but in the present report they are included with the Nasina series, as the lithological characters have proved to be very similar.

Folds and faults.

Structure.—The Nasina series include, so far as known, the oldest rocks in the Yukon Territory. They have a wide distribution but the various areas are comparatively small and differ greatly in degree of deformation they have undergone in the course of their long history. In the least disturbed areas the alternating shales, flags, quartzites and limestones, which represent the series, are bent in easy folds with dips seldom exceeding 30°. In the more disturbed areas the dips are high, and sharp flexures, often passing into faults, are frequent. In some of the sections the argillaceous members of the series are distinctly cleaved, but the principal divisional planes everywhere correspond with, or are parallel to, the original lines of bedding.

The principal area in the Klondike occurs along Indian river and is cut transversely by the valley of the Yukon. The beds have a general synclinal attitude, both limbs of the syncline dipping towards a granite mass situated above Ensley creek. The beds in the southern limb dip regularly northward at angles of from 30° to 50°. The lowest beds brought to the surface by the syncline occur north of Reindeer creek. They are interbanded with granite gneiss and are themselves altered locally into fine-grained dark mica gneisses. The northern limb of the syncline is less regular than the southern one. The dips are high, often exceeding 60°, and the beds in many places are sharply plicated. The strongest crumpling occurs half a mile south of the northern edge of the formation. The strata here, for a width of several hundred yards, are bent, twisted and corrugated in an exceedingly complicated manner, while the beds above and below are comparatively regular. Besides the crumpling of the rocks in the northern limb of the syncline, they are also cut by numerous faults produced at different periods and often intersecting each other. The faults are small, as a rule, and in no place was any great displacement of the rocks observed. The throw is usually normal, but in some cases appeared to be reversed.

Notwithstanding the more disturbed and broken condition of the rocks in the northern limb of the syncline, they are less altered than the beds occupying a corresponding position in the southern limb. This is doubtless due to the absence of the intrusive sheets of granite gneiss associated with the latter.

The Nasina schists along the Klondike river are only shown in occasional exposures and no details in regard to their structure were obtained. The small areas inclosed in the igneous schists of the Klondike series conform in dip and strike very closely to the latter.

Lithology.

The rocks of the Nasina series represent altered argillaceous and siliceous sediments, the different varieties depending on the varying proportions of these originally present. The more siliceous sediments have hardened into micaceous quartzites and these pass gradually into gray quartz mica-schists, and, by a further decrease in the amount of silica present, into dark, glossy mica-schists. The minerals present are very similar in all the varieties but vary in importance. Quartz is the most abundant constituent. In thin sections it appears as a mosaic of small angular and sub-angular grains pressed closely together and arranged in narrow bands and areas separated by lines of sericite and biotite. The grains are occasionally drawn out in the direction of the schistosity. The quartz is usually associated with a subordinate quantity of feldspar. Biotite is conspicuous in most of the sections. The leaves are small and are usually arranged parallel to the planes of schistosity. Sericite is abundant, and chlorite calcite, kaolin, magnetite and pyrite are occasionally present, and more rarely garnet and tourmaline. The dark colouration is due largely to carbonaceous material disseminated in fine particles through the rock.

The beds and bands of crystallized limestone associated with the siliceous and argillaceous schists are usually more or less siliceous and, in places tremolite, sericite and other secondary minerals are developed in them.

Green chloritic and actinolitic schists form an important part of the Nasina series on the Stewart river and other places, but are not prominent in the main area of these rocks in the Klondike district. A band of green schists, consisting mostly of chlorite and epidote with some unstriated feldspar, probably albite, occurs in the Klondike valley opposite the mouth of Hunker creek.

KLONDIKE SERIES.

General remarks.—The Klondike series are the principal gold-bearing rocks of the Klondike district. They consist mainly of light-coloured sericite schists associated with a subordinate quantity of greenish chloritic schists. The two varieties often occur in alternating white and green bands easily distinguished in the field, but in most cases both sericite and chlorite are present in variable quantities, and the predominence of one or the other gives character to the rock.

Igneous schists.

The schists of these series differ from the Nasina schists in being mainly, if not altogether, of igneous origin. The original rocks varied widely in character, as both acid and basic surface and deep-seated varieties were present, and possibly tuffs as well. The principal types recognized consist of quartz porphyries, granite porphyries and basic porphyritic rocks. The former are now represented by sericite schists and ordinary and augen gneisses, and the latter by chlorite and occasionally amphibolite schists. All the varieties have a common schistosity which is also conformable, as a rule, to that of the bordering clastic schists.

The relative ages of the bands of sericite and chlorite schists could not be determined. The latter, in some instances, suggest dikes, but both sets are sheared alike and have yielded in equal measure to the dynamic and other metamorphic agencies which have affected the region. The granite gneiss probably represents the same magma as the quartz porphyry, cooled at a greater depth.

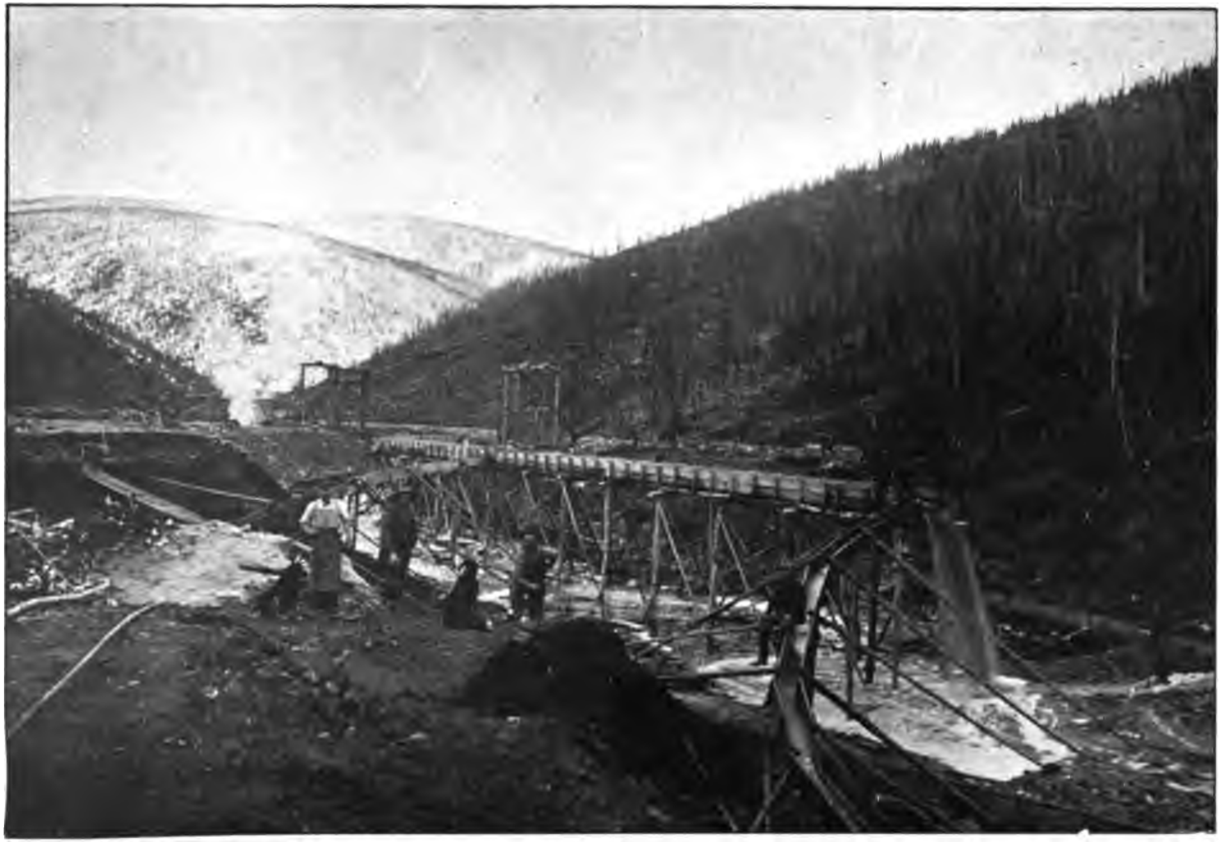
Enclosures.

The Klondike schists often inclose small irregular areas and short bands of dark clastic schists identical in character with the rocks of the older Nasina series and probably representing undissolved portions of this formation. They are also pierced at various points by small stock-like areas or short oblong dikes of quartz porphyry, rhyolite and andesite. These rocks are much younger than the schists. They have not been crushed and have suffered little alteration of any kind.

Distribution and correlation.—The Klondike schists cross the central portion of the Klondike district in a band varying in width from ten to twenty miles and striking in a N.W. and S.E. direction. The extension of the band beyond the limits of the Klondike district has not been traced out. The formation is bordered on both sides by the dark schists of the Nasina series. The southern contact follows a nearly straight line. The northern boundary is more intricate, as it often bends sharply around angular bays of the dark schist and, in places, the two series of schists occur for some distance in alternating bands.

Occurrences at other points.

Sericite schists, identical in character with the Klondike schists, occur at various points on the Yukon territory, notably in the Fortymile district, on Henderson creek, and in the Stewart valley. They are closely associated everywhere with the Pelly gneisses and in some instances, at least, simply represent an extreme schistose phase of these rocks. On Henderson creek, the schists and gneisses occur in alternating bands manifestly identical in age and origin, and in the Fortymile district the gneisses are followed crossing the strike by



CLAIMS 16-17 "ABOVE," HUNKER.

sericite schists agreeing with them in dip and strike. The exposures here are imperfect and the exact contact was not seen.

In the Klondike district the sericite schists of the Klondike series in their extension eastward pass into or are replaced by granite gneisses, and gneisses also occur on Indian river along the southern border of the area. At the latter point, the gneisses pass gradually, going northward, across the strike into finely foliated schists.

A portion of the Klondike schists, a least, can therefore be referred with tolerable certainty to the age of the Pelly gneisses, and it is probable that the whole series belongs to the same period.

Structure.

The rocks of the Klondike series are everywhere foliated, but have suffered unequally in this respect. In the less schistose varieties, the rock is hard, imperfectly cleavable, and weathers into angular striped blocks, or flags of moderate thickness. The more schistose varieties are soft and cleave easily in the direction of the schistosity into thin leaves or plates often an inch or more in thickness. Crinkled surfaces occur in both the hard and soft varieties, but are exceptional, and sharp plications are also rare, although present, at a few points. The planes of schistosity are not influenced in direction by differences in the character of the rocks, but traverse all kinds indifferently, and often pass from the sericite to the chlorite schists at angles to the plane of contact between them.

Strike.

The strike is generally N.W. and S.E.—that is, parallel to the longest axis of the area, but to this rule there are many exceptions. On Bonanza creek the schists follow a serpentine course, and in the Yukon valley, near Baker creek, and on the ridge between Carmacks fork and Upper Bonanza creek, they strike almost at right angles to the general direction. The schistosity is periphyral in character, and the changes in the direction of the strike are commonly due to corresponding changes in the direction of the outline of the area. A secondary cleavage, cutting the main schistosity almost at right angles, was noted at a few points at Bonanza creek, but is not general.

Small folds in the schists occur at a few points, but over the greater part of the area the dip is persistently S.W. The low angle of the dip, in many places, is remarkable in the case of such a highly altered series of rocks. On Dominion ridge, the Dome ridge, and other places, dips of less than fifteen degrees are common, and high dips are exceptional throughout the whole area.

Faults.

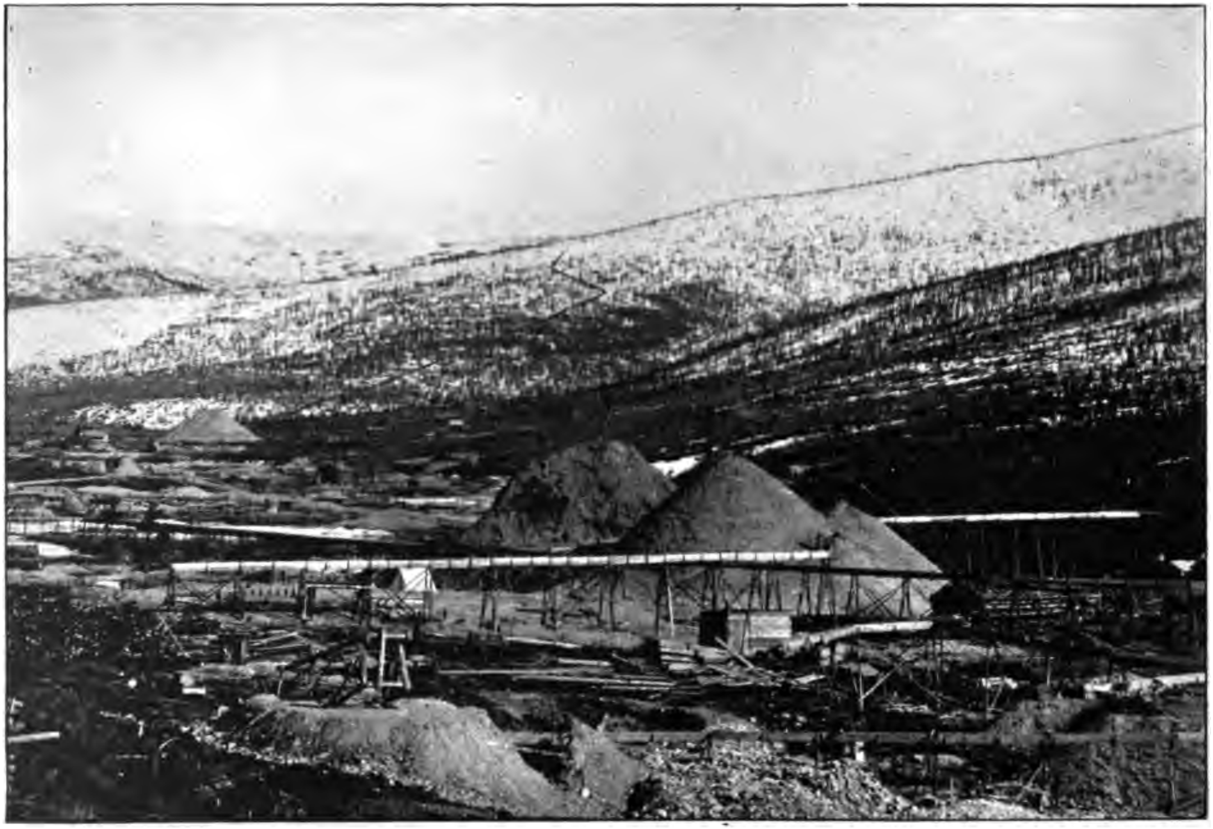
The Klondike schists, like the Nasina schists, are cut repeatedly in places by small faults, the observed displacements ranging from a few inches to a few feet in extent. A quartz vein, uncovered for sixty feet, in the Violet group of claims south of Eldorado creek, is broken by several faults with small throws, and at one point bends suddenly and follows for a short distance an old cross-fracture plane. The faultings here evidently belong to two periods, one younger than the quartz vein, and the other older or contemporaneous with it. The faults are seldom conspicuous, or even noticeable, except in the few places where the beds have been bared by mining operations, on account of the depth of the general surface decomposition of the rocks.

Sericite schists.—The principal rock in the Klondike series consists of a white or light green sericite schist originating largely from the deformation and alteration of quartz porphyries or allied rocks. The porphyritic character of the rock in places is still evident in hand specimens, and in the crushed varieties in usually easily recognizable in thin sections. The principal minerals of the sericite schist are sericite, chlorite, quartz, orthoclase and plagioclase. Biotite is conspicuously absent in most of the sections. Sericite is the most abundant micaceous mineral. It is usually associated with chlorite and this mineral is often present in sufficient quantities to give character to the rock. The quartz in the less altered varieties occurs in bluish blebs of moderate size wrapped round by small scales of sericite and chlorite, arranged in parallel leaves. In some of the specimens the quartz blebs are still unbroken; in others more or less granulation has occurred, resulting in the production of short tails. The quartz grains are occasionally accompanied by angular crystals of feldspar, and in a few sections feldspar is the only porphyritic mineral recognizable macroscopically. The feldspar is usually in an advanced state of decomposition and difficult to determine specifically. Both orthoclase and plagioclase are present, the former predominating.

The schists characterized by uncrushed quartz and feldspar phenocrysts are exceptional and occur mostly in the western part of the district. They have an irregular distribution and grade through varieties in which the porphyritic character can still be detected in thin sections, into schists similar in mineralogical composition, but so completely altered that their origin becomes obscure. The latter may possibly be derived, in part at least, from acid tuffs.

Granite gneiss.

A section from Eldorado creek to Indian river below the mouth of Quartz creek shows a gradual transition from typical fine-grained sericite schists to coarse augnen gneisses representing deformed granite porphyries. The gneisses are well foliated and consist of porphyritic individuals of orthoclase, plagioclase and occasionally quartz, scattered through a



A portion of Dominion Creek, looking down from 10 "above" lower Discovery.

[p. 18.]

ground-mass of the same materials. Sericite, chlorite and biotite are also present, the latter usually partly chloritized. Epidote and sphene are common accessory minerals and allanite is occasionally found. Similar gneisses occur on the lower part of Sulphur creek and also on the crest of the ridge separating Lower Dominion from Flat creek. In the latter locality, they pass into a coarse-grained augen gneiss, the feldspar lenses often measuring two or three inches in length. In some of the sections here, hornblende is present as well as biotite.

Microscopical description.

The field evidence of a close genetic connection between the schists and gneisses is confirmed by the microscopic study of thin sections which show all gradations from typical quartz porphyries to granite porphyries.

The following general description of the microscopic character of the sericite schists and associated rocks is contributed by Dr. A. E. Barlow.

"The rocks of the Klondike series are shown, by the examination of the thin sections under the miscroscope, to be altered quartz and granite porphyries. They usually possess a very marked foliation and schistosity accentuated by the development of various secondary minerals as a necessary accompaniment of the pronounced dynamic action to which they have been subjected. The altered quartz porphyries are soft, unctuous to the touch, and have a greenish or yellowish colour and pearly lustre on the cleavage surface, due to the abundant development of the secondary micaceous minerals. The granite-porphyries, on the other hand, are more massive, foliated rather than schistose, are harder and generally vary from grayish to reddish in colour. From a petrographical point of view, both are extremely interesting and instructive as furnishing an undoubted transition from the typical massive types, marking the varieties which have suffered little or no mechanical deformation or alteration, to a nacreous schist or gneiss in which the original phenocrysts of quartz and feldspar have been altogether reduced into lenticular areas, and often fairly continuous bands of granulated material with the development of sericite, chlorite and other products of decomposition along the planes of shearing. As a primary result of the extreme pressure and accompanying stretching to which these rock masses have been subjected, the remaining ungranulated portions of the original phenocrysts of quartz and feldspar, and especially the former, show pronounced wavy or undulous extinction. With an increase of the dynamic metamorphism this condition of strain is relieved by the development of a series of irregular cracks, and the formation of "tails" of granulated material in the wake of the fragment of crystal. Still further application of the forces of stretching causes the complete obliteration of the original phenocrysts and the production of lenticular areas and broken bands of a comparatively coarse-grained mosaic of quartz and feldspar. The porphyritic individuals of quartz are the first to suffer, and many cases were noticed in which most, if not all of the quartz phenocrysts had undergone advanced granulation, while those of feldspar had suffered little or no deformation. Accompanying such processes of shearing, sericite or hydrous muscovite in pale yellowish or colourless scales and plates is developed in wide, wavy approximately parallel bands sweeping gracefully through and among the individuals of quartz and feldspar. Chlorite, usually accompanied by small crystals, grains and irregular aggregates of epidote and zoisite, is often present, and in some of the more basic and feldspathic varieties, replaces, in large part at least, the sericite. Biotite, either fresh or in the various stages of decomposition into chlorite, is usually present in considerable amount in irregular plates and hypidiomorphic individuals in the granite porphyries. Leucoxene and sometimes the more normal sphene is also very commonly represented in irregular grains derived doubtless from the alteration of ilmenite. Magnetite and pyrite, the latter decomposing to limonite, also occur more sparingly. Occasional crystals and fragments of apatite, zircon and hornblende were likewise noticed. Calcite often occurs and is sometimes abundant in irregular and sharply defined individuals.

Secondary quartz.

"By the failure on the one hand of the quartz phenocrysts and a corresponding increase in the development of those of feldspathic composition, the quartz porphyries show an unbroken transition into the granite porphyries, while on the other hand the frequent abundance of phenocrysts of plagioclase marks a distinct passage into the porphyrites. Silicification or the infiltration and deposition of secondary quartz has likewise contributed much to the formation and consolidation of the rock masses, in many cases effectually masking their original structures. So complete has been this process of hardening that even the most minute cracks and fissures have been completely occupied by the vein-like quartz. The origin of such silica is doubtless pegmatitic, representing the latest, and consequently extremely acid and hydrated, secretions of the magma, evidencing the expiring efforts of the widespread vulcanism to which the enclosing rocks owe their formation. This secondary quartz varies very greatly in the amount and extent of its development, from the small lenticular bands (which can only be detected microscopically and are distinguishable with difficulty from the similar clear areas representing deformed and granulated phenocrysts) to large veins.

Other occurrences of similar rocks.

"Rocks almost identical in structure and composition have been described in detail by Lawson * and Coleman † and mentioned by Smith ‡ and McInnes §, as occurring in the district to the northwest of Lake Superior, while Williams,‖ on the south of Lake Superior, gives a very minute recital of the structural features noticed in the altered quartz and granite porphyries of the Menominee and Marquette regions of Michigan.

"Similar deformed schistose porphyries have not escaped the attention of the European geologists, and Prof. C. E. Weiss** of Berlin in 1884, describes altered quartz porphyries near Thal in Thuringia while Dr. C. Chelius, †† has drawn attention to the very closely related deformed granite porphyries of the Odenwald (Hesse-Darmstadt).

Tuffs.

"In some of the areas represented by the typical specimens it is certain that these schistose porphyries are accompanied by acid tuffs, while certain micaceous schists and quartzites, composed chiefly of interlocking grains of quartz with a much smaller, though varying proportion of feldspar and micaceous minerals, may possibly be epiclastic in origin resulting from the consolidation of truly aqueous sediments. If this latter supposition be correct, the application and long continuance of the forces of pressure and stretching, accompanied by complete recrystallization, have produced in all a complete and perfectly interlocking quartzo-feldspathic mosaic, so that nothing can now be asserted, with any degree of certainty, in regard to any structure which they might originally have possessed. The exact diagnosis and correct interpretation of many of these rocks is thus manifestly extremely difficult and in some cases impossible; and even with the advantage of critical study and comparison of the numerous and carefully selected microscopic sections, aided by the detailed field work already undertaken, it has been found hopeless to pronounce decisively regarding the position of some of the examples studied."

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* Ann. Rep. Geol. Surv. Can. 1887-88, Part I, pp. 85-90F.

† Ann. Rep. Bureau of Mines, Ont., 1894, pp. 84, 87, 88.

‡ Ann. Rep. Geol. Surv. Can. 1890-91. Report G.

§ Ann. Rep. Geol. Surv. Can. 1897. Report H.

‖ Bull. U.S.G.S. No. 62, 1890, pp. 148-154.

** Jahrbuch preuss. geol. Landesanstalt fur 1883 pp. 213-237 Berlin, 1884.

†† Notizblatt des Vereins für Erdkunde zu Darmstadt, 4, Folge, Heft 5, 1885, p. 29.

Chlorite schists.

Chlorite schists occur both as gradual transitionsfrom the sericite schists and in separate bands alternating with them. In the former case, they doubtless represent the more basic portions of the same rocks from which the sericite schists originated. They are similar to the latter in structural and general character and differ from them, chiefly in containing a greater proportion of chlorite.

The origin of the bands of chlorite schists is not so clear and it is possible that some of them represent latter basic intrusions. No direct proof of this is obtainable in the field as both series have been sheared and altered alike, and all the ordinary marks of eruptive contact have been destroyed. The mineral constituents have also been so granulated and altered that little trace of the original structure of the rock remains. Thin sections show areas made of interlocking mosaics of quartz, orthoclase and plagioclase with some calcite, separated by matted aggregates of chlorite and schists arranged in thin curving bands.

Variations.

Variations from the ordinary type occur in a few places. In the upper part of Dominion creek the schist has a coarser foliation than usual and contains large individuals of quartz and plagioclase in addition to the usual granulated mosaics. Its composition suggests a derivation from a porphyrite. A band of green schist sprinkled with dark hornblende chrystals, probably a sheared diorite, crosses the Dome ridge near the head of Bonanza creek, and an actinolite schist occurs on Hunker creek above Goldbóttom.

MOOSEHIDE DIABASE.

The rocks referred to under this name outcrop along the lower part of the Klondike valley and on Moosehide mountain, north of the Klondike. They are also found on the western bank of the Yukon valley, opposite Moosehide mountain.

Character of diabase.

The Moosehide diabase is a greenish medium-grained rock usually sheared. It has yielded less in this respect than the quartz porphyries of the Klondike series and often appears almost massive. It is everywhere greatly altered and in thin sections exhibits great variety. The less altered specimens show a well marked ophitic structure, although the original augite has in most cases disappeared. Secondary hornblende is nearly always present. Occasional small areas and narrow bands consist almost entirely of fibrous actinolite. passing in some places into a coarse asbestus. Serpentine occurs in all the sections, and an almost pure serpentine now represents the original rock on both sides of the summit of Moosehide mountain. Chlorite, calcite and zoisite in varying quantities are common decomposition products, and epidote and sphene, the former often in considerable abundance, are present in most of the sections.

Relation to Klondike schists.

The relationship of Moosehide diabase to the Klondike schists in regard to age is uncertain but it is probable that they are nearly contemporaneous and belong to the same ancient period of igneous activity. The deformation of the diabase is less complete than that of the quartz porphyries, but the constituent minerals have suffered an equal amount of alteration, and both rocks are faulted alike and are traversed by similar small quartz veins.

UNALTERED SEDIMENTARY ROCKS.

TERTIARY (KENAI SERIES?).

Distribution of unaltered sedimentaries.

Several areas of unaltered sedimentary rocks occur, occupying depressions in and around the outskirts of the Klondike district. The largest of these commences at the Klondike valley above Rock creek and extends in a W.N.W. direction to Cliff creek, a distance of about seventy miles. The width of the area has not been determined but probably averages ten miles. It lies along the base of the Ogilvie range and is separated from the Yukon by a narrow strip of the older schistose rocks.

The rocks consist mainly of slightly coherent sandstones with conglomerates alternating with dark and coloured clays and shales, carbonaceous shales and, occasionally, lignites. No general section has so far been measured and the thickness is unknown. The sandstones are often arkose in character, showing in thin sections angular and subangular grains of quartz, turbid feldspars and colourless micas. Calcite and limonite are also usually present.

The beds dip, as a rule, at moderate angles but are somewhat irregular in this respect, the inclination often changing suddenly, both in degree and in direction. High dips occur occasionally and in places the beds are broken and faulted.

Age.

The age of the lignite-bearing beds in the basin has been determined by Dr. Knowlton on the evidence of fossil leaves collected by Mr. A. J. Collier, of the United States Geological Survey, to be Upper Eocene*. They are, therefore, equivalent or nearly so, to the Kenai series.

A small area of Tertiary rocks occurs in the valley of Last Chance creek, just above the junction with Hunker creek. Since their deposition, considerable rock movements have taken place, as they are infolded with the schists on which they rest. The series here, in addition to the usual shales, sandstones and conglomerates, include beds of decomposed andesite tuffs.

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*U.S. Geol. Bull. No 218, p. 25.

Similar beds, cut by andesites and diabases, cover a considerable area south of Indian river, above and below the mouth of Quartz creek. They occupy here a remarkable depression, surrounded on all sides, except where crossed by the Indian river valley, by high ridges built of the older schists. From the centre of the depression rise Haystack mountain and the Dismal dome, two prominent andesite cones, and a number of other lower andesite hills. The origin of the depression is probably due to volcanic action.

The beds in this area are lightly folded and consist of soft light grayish arkose sandstones, yellowish and dark tufaceous sandstones, light and dark shales and clays, agglomerates and conglomerates. In addition to these, a small bed of lignite occurs in a branch of Ruby creek, a tributary of the Indian river. The conglomerate in some places resembles the high-level white channel gravels of Bonanza and other Klondike creeks. It occurs in heavy bands usually associated with sandstones and is often conspicuously white in colour. The pebbles are largely derived from quartz veins and are embedded in a matrix of quartz grains and sericite. They are smaller and better-rounded than the pebbles in the white channel gravel. The conglomerate is usually fairly well indurated, and in places near the andesite masses has been cemented, probably by infiltrating siliceous water, into an exceedingly hard rock. It carries small values in gold and some attempts have been made to mine it.

The shales and sandstone in the Indian River area hold fragments of fossil plants, but none of these have so far been identified.

A large area covered by beds referred tentatively to the Tertiary, but which may be older, occurs south of the district along Sixtymile river. The apex of this area reaches the Yukon below the mouth of Indian river. Sandstones and shales and andesite and rhyolite tuffs occur, here associated with great sheets of andesite.

FLAT CREEK BEDS.

Area of Flat Creek beds.

The wide depression between the Klondike hills and the Ogilvie range is covered with alternating beds of silts, sands, clays and gravels, for which the name Flat Creek beds is proposed. These beds have a thickness, on the lower part of Flat creek, of six hundred feet, and a width of from eight to fifteen miles. They extend from a point north of Twelvemile river S. E. across the Klondike to the Stewart. Between the Stewart and Klondike rivers, they rest on the older schists and granites, and, north of the Klondike, on the older Tertiary.

The Flat Creek beds have been partially destroyed by streams flowing from the Ogilvie range, and are carved into a series of flat-topped plateaus often lined with low terraces. The beds are nearly everywhere concealed and only a couple of small imperfect sections were seen in the locality visited. These show flat-lying beds of loose gravel alternating with yellowish and grayish sands, sandy clays and silts. The gravels are well-rounded and consist of the slates, cherts, quartzites, diabases, and granites occurring in the Ogilvie range. They are auriferous in places but no pay values have so far been found in them.

The age of the Flat Creek beds is uncertain; they are referred to late Tertiary, but it is possible that a portion of them at least may represent extramorainal material washed out from the Ogilvie range during the glacial period.

MASSIVE IGNEOUS ROCKS.

GRANITE.

Granite area.

Granite occurs on the Yukon river about three miles below the mouth of Indian river. The area has a width, where cut by Yukon river, of less than two miles, but widens out towards the east. The boundaries of the area as shown on the map are only approximate, as its contact with the surrounding schists is seldom seen. Good exposures occur on the right bank of the Yukon, but the area narrows crossing the valley, and is only found at one point on the left bank.

The granite in this area is grayish in colour when fresh, and coarsely granular in texture as a rule, although in places it becomes distinctly porphyritic. It is usually unfoliated but is slightly sheared in places. Microscopically, it consists essentially of quartz, orthoclase, plagioclase (mostly oligoclase,) bleached biotite, and some hornblende, mostly altered into chlorite. The feldspars are usually decomposed and include scales and grains of sericite, and calcite. Almandine garnet is a frequent accessory mineral.

DIABASE.

Diabase areas of dikes.

An area of diabase three miles in width is cut by the Indian river valley above New Zealand creek. The diabase is a dark-coloured, coarse-textured and quite massive rock. In thin sections it shows a well marked ophitic structure. The lath-shaped labradorite individuals usually inclose brownish augite but occasionally the latter is replaced by greenish serpentine which may have been derived from olivine. Other minerals present include biotite in small quantities, and grains of pyrite and magnetite.

Wide diabase dikes, similar in character to the Indian river diabase, occur in the Yukon valley opposite the mouth of Indian river, cutting rocks referred to the Tertiary, and several small dikes cross Eldorado creek near its mouth, cutting the Klondike schists. Thin sections of these show, in addition to the usual minerals, large apatite prisms.

ANDESITES, ETC.

Andesite rocks.

Andesite dikes and stocks are common in the Klondike district, and rocks representing andesite-flows are also prominent. The andesites cut the old schistose rocks in places, but usually occur in connection with the Tertiary beds. Some of them are younger than the latter while others appear to be contemporaneous with them. Tufaceous beds, usually andesitic in character, occur on Last Chance creek and other places, interbanded with the shales and sandstones of the Tertiary series.

Indian River area.

The largest andesite area in the district occurs in the Tertiary depression south of Indian river. Two prominent elevations which rise from this depression, known as Haystack mountain and the Dismal dome are built entirely of this rock, and it also spreads over a considerable part of the bordering lowlands. Haystack mountain evidently represents the core of an old volcanic centre partially destroyed by erosion.

The andesite from Haystack mountain is a grayish, moderately fine-grained, and often distinctly porphyritic rock. In thin sections it shows a microfelsitic ground mass usually more or less decomposed. In this are embedded long tabular crystals of plagioclase and large rounded individuals of greenish hornblende bordered by opaque rings consisting of ilmenite and leucoxene. Augite is also usually present and, less frequently, scales of brownish biotite.

Yukon River area.

A second area of andesites, largely effusive in character, occurs on the Yukon river opposite and below the mouth of Indian river. The andesites, associated with Tertiary sedimentary rocks, are exposed along the left bank for several miles, and at one point, cross the Yukon valley and spread out along the foot of the slope on the right bank. The rock here is vesicular, the cavities often containing chalcedonic material. It is a hornblende-augite-biotite andesite very similar to the Indian river variety. The ground mass is less individualized and includes some glassy matter. The andesites on the left bank of the Yukon are traversed in places by wide diabase dikes.

A small area of hornblende andesite borders the Tertiary area at the mouth of Last Chance creek. The andesite here is coarser-grained than usual and is badly decomposed. In thin sections it shows a felted ground mass of plagioclase and hornblende, the latter often altered into chlorite.

Propylite.

A light gray medium-grained granular rock occupying a small area on Whiskey hill on Upper Hunker creek, is very similar in structure and composition to Richthofen's "propylite."* The plagioclase individuals of which it principally consists have a rude, ophitic structure, the interspaces being filled largely with unstriated feldspar and quartz, and less frequently with brown biotite and green hornblende, the latter often in perfect crystals. Magnetite, apatite and sphene are also present.

A somewhat similar rock was found on Indian river, apparently passing into the andesites, of which it probably represents a deep-seated phase.

QUARTZ PORPHYRIES, ETC.

Areas of quartz porphyry.

The quartz porphyries are the youngest igneous rocks in the district. They occur in numerous, small, oblong areas, everywhere throughout the region, both in the valleys and on the ridges. The areas usually measure from one to two hundred yards in width and from a quarter to half a mile in length, and might be classed in most cases as wide, short dikes. They were found to be intrusive through the schists and older rocks in all cases where contact exposures were available for study.

The quartz porphyry, macroscopically, is a pale yellow compact rock sprinkled with small phenocrysts of dark quartz and yellowish decomposed feldspar. In thin sections it shows a microgranitic ground mass through which individuals of quartz, orthoclase and plagioclase are porphyritically distributed. Quartz is the most abundant porphyritic mineral, and occurs both in rounded and corroded forms and in perfect dihexehedral crystals. The feldspars usually exhibit good crystallographic outlines.

The various dikes and areas of the recent acid volcanic rocks dotted over the district agree, as a rule, very closely in character, but in a few cases the microgranitic ground mass is replaced by a glassy base, and the rock might be classed as a rhyolite rather than as a quartz porphyry. A specimen from a small area, probably effusive in character, situated on the right bank of the Klondike river, seven miles above Rock creek, showed, in thin sections, a glassy ground mass with fluidal structure, holding microlites and spherulites of quartz and feldspar. The porphyritic individuals, in addition to those in the quartz porphyrys, included occasional scales and plates of brown biotite.

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* Mem. California Acad. of Sc. Vol. I., part II., 1868.

SERPENTINES (PERIDOTITES).

Areas of serpentine.

A long narrow band of serpentine occurs on the ridge separating the upper part of Hunker creek from the Klondike river. At the head of Leotta Creek it rises into a prominent peak known as Leotta mountain. The serpentine lies near the northern boundary of the Klondike schists, and cuts both these and the dark schists of the Nasina series.

The serpentine in Leotta mountain is a dark greenish, compact rock, often weathering into yellow and brown shades. In places the green base is mottled with yellow, the latter representing the less altered portions. Thin sections exhibit occasional cores of brownish pyroxene and almost colourless olivine, showing that the rock originated from a peridotite. Some calcite is also usually present, and grains of dark iron ore (probably magnetite) occur in most of the sections.

The intrusion of the peridotite occurred at a comparatively recent period, as it has not been sheared, and is not traversed by the veins and dikes which cut all the older rocks.

A second serpentine area occurs on the summit of the Hunker Klondike ridge, nearly opposite the mouth of Hester creek. The serpentine here is a harder and much tougher rock than that occurring at Leotta mountain. In thin sections it is seen to consist of small scales and fibres of greenish serpentine, matted together in an extremely intricate manner. No cores of the original minerals were observed. The contact of this mass with the surrounding schists was not seen.

GRAVELS OF THE KLONDIKE GOLD FIELDS.

A section across the valley of any of the gold bearing streams entering the Klondike shows a comparatively narrow trough-like depression below, from 150 to 300 feet deep, bordered on one or both sides by wide benches beyond which the surface rises in easy, fairly regular slopes up to the crests of the intervening ridges. The benches represent fragments of older valley-bottoms partially destroyed by the excavation of the present valleys. Narrow, rock-cut terraces occur at intervals between the level of the old valley-bottoms and the present level.

Classification of gravels.

Auriferous gravels occur on the present valley-bottoms, on the portions of the old valley-bottoms still remaining and on the rock terraces cut into the slopes connecting them. They may be classified as follows, beginning with the youngest.

Low level gravels.	Gulch gravels,	
	Creek gravels,	
	River gravels.	
Gravels at intermediate levels.	Terrace gravels.	
High level gravels.	River gravels,	
	" White channel " gravels,	White gravels.
		Yellow gravels.

LOW LEVEL GRAVELS.

Character of Low level creek gravels.

The low level creek gravels are the most important gravels in the district. These gravels floor the bottoms of all the valleys to a depth of from four to ten feet. They rest on bedrock usually consisting of decomposed and broken schists, and are overlaid by a sheet of black frozen muck ranging in thickness from two to thirty feet or more. They are local in origin and consist entirely of the schists and other rocks outcropping along the valleys. The schists pebbles are usually flat round-edged discs measuring one to two inches in thickness and two to six inches in length. They constitute the greater part of the deposit, but are associated with a varying proportion of rounded and subangular quartz pebbles and boulders, and, less frequently, with pebbles derived from the later eruptive rocks of the region. The pebbles are loosely stratified, are usually embedded in a matrix of coarse reddish sand and alternate in places with thin beds of sand and muck.

Fossils.

The creek gravels frequently inclose leaves, roots and other vegetable remains and also the bones of various extinct and still existing northern animals, such as the mammoth, the buffalo, the bear, the musk-ox and the mountain sheep and goat.

The Gulch gravels occupy the upper portions of the main creek valleys and small tributary valleys. They differ from the creek gravels in being coarser and more angular. A considerable proportion of their material consists of almost unworn fragments of schist washed down from the adjacent slopes. They contain the same vegetable and animal remains as the creek gravels.

The only river gravels of the district proven, so far, to contain gold in paying quantities occur in the wide flats bordering the lower portion of the Klondike river below the mouth of Hunker valley. The river gravels consist of quartzite, slate, chert, granite and diabase pebbles largely derived from the western slopes of the Ogilvie range. They are harder and better-rounded than the creek gravels, a necessary result of the greater distance travelled.

TERRACE GRAVELS.

Terraces.

Rock terraces occur at various points cut into the steep slopes of the present valleys. They were produced during the deepening of the valleys, and are simply remnants of former valley-bottoms. They are small, seldom exceeding a few yards in width and a few hundred yards in length, irregular in distribution, and occur at all elevations up to the bottoms of the old valleys. The terraces support beds of gravel, usually from six to fifteen feet in thickness, very similar to that in the creek bottoms, but showing somewhat more wear. The terrace gravels, like the creek gravels, are overlaid, as a rule, with muck, and at one point on Hunker creek were found buried beneath a hundred feet of this material.

HIGH LEVEL GRAVELS.

High level river gravels.

High level gravels are extensively distributed along Bonanza and Hunker creek and some of their tributaries, and also occur on Eldorado, Bear, Quartz, Nine Mile, and Allgold creeks. They consist, principally, of ancient creek deposits, overlaid near the mouths of some of the valleys by gravels laid down by the Klondike river, when it ran at a much higher level than at present, and occupied a somewhat wider valley.

These gravels occur at various points along the Klondike river. In the Klondike district they are found covering the small plateaus in which the ridges separating Bonanza and Hunker creeks from the Klondike river terminate. They rest, in both places, on high level creek gravels at an elevation of about 450 feet above the present valley-bottoms. They have a thickness of from 150 to 175 feet, and consist principally of well-rolled pebbles, of quartzite, slate, chert, granite, diabase and conglomerate embedded in a matrix of gray sand and derived, like those in the present stream, from the western part of the Ogilvie range. The high level river gravels are reported to contain gold in paying quantities at Acklens farm, a name given to a portion of the bench on the right limit of the Klondike, two miles above its mouth, but are generally of little economic importance.

High level creek gravels.

High level creek gravels.—The high level creek gravels consist principally of the important deposit known as the quartz drift white wash or white channel gravels. The latter name is now generally used by the miners, and is adopted in this report.

White channel gravels.

The white channel gravels are ancient creek deposits laid down in the wide, flat-bottomed valleys which characterized the region previous to the last general upraise. After their deposition, the country was elevated 600 to 700 feet, and the increased grades acquired by the streams enabled them to cut down through their old gravel beds into the bedrock beneath, and to excavate the steep-sided trough-like valleys in which they now run. The old gravels now occur on wide benches bordering the present valleys at elevations of from 150 to 300 feet above them, the elevation generally increasing down stream. Their distribution along the valleys is irregular, as a large portion of the deposit was destroyed during the deepening of the main valleys and the tributary valleys and gulches.

The general character of the white channel gravels is remarkably similar in the various Klondike creeks, but differs considerably from the ordinary type of stream deposits in other regions. They consist of a compact matrix of small, clear, little-worn and often sharply angular grains of quartz and scales of sericite thickly packed with rounded quartz pebbles and rounded and sub-angular and wedge-shaped quartz boulders often two to three feet in diameter. Flat and sub-angular pebbles of sericite schist, the principal rock of the district, are also present, but in much smaller numbers than the quartz constituents. The schist pebbles are usually decomposed and crumble rapidly when thawed out. The deposit is always stratified, but, except in rare instances, there has been no sorting of the various constituents into separate beds, and the composition is very uniform throughout. The colour is characteristically white or light gray due to the preponderance of the quartz constituents and the leaching out of the greater part of the iron. The colour is darker and the sands are noticeably coarser towards the limit of the deposit on the upper part of the creeks.

The white channel gravels vary in thickness from a few feet to 150 feet and in width from 100 feet to half a mile or more. The deposit increases in volume descending the stream, and attains its greatest development near their mouths.

Yellow gravels.

The white compact gravel deposit described above is overlaid in places by loosely stratified gravels known as the yellow gravels. The latter are of a rusty colour, are more distinctly stratified than the white gravels and consist mainly of flat schist pebbles lying loosely in a coarse sandy matrix. Quartz pebbles and boulders are also present, but are much less abundant than in the white gravels.

These upper gravels are not so widely distributed as the white gravels but are present on several of the Bonanza hills and at points along Hunker creek. At Gold hill, on Bonanza creek, the white gravels occur as a buried ridge bordering the present valley, and the depression between them and the southern slope of the old valley is filled with yellow gravels to a depth of 115 feet. The same relationship between the two deposits obtains at Adams hill and probably at other places, but is only determinable where shafts have been sunk to bedrock across the whole width of the old valley.

Absence of fossils.

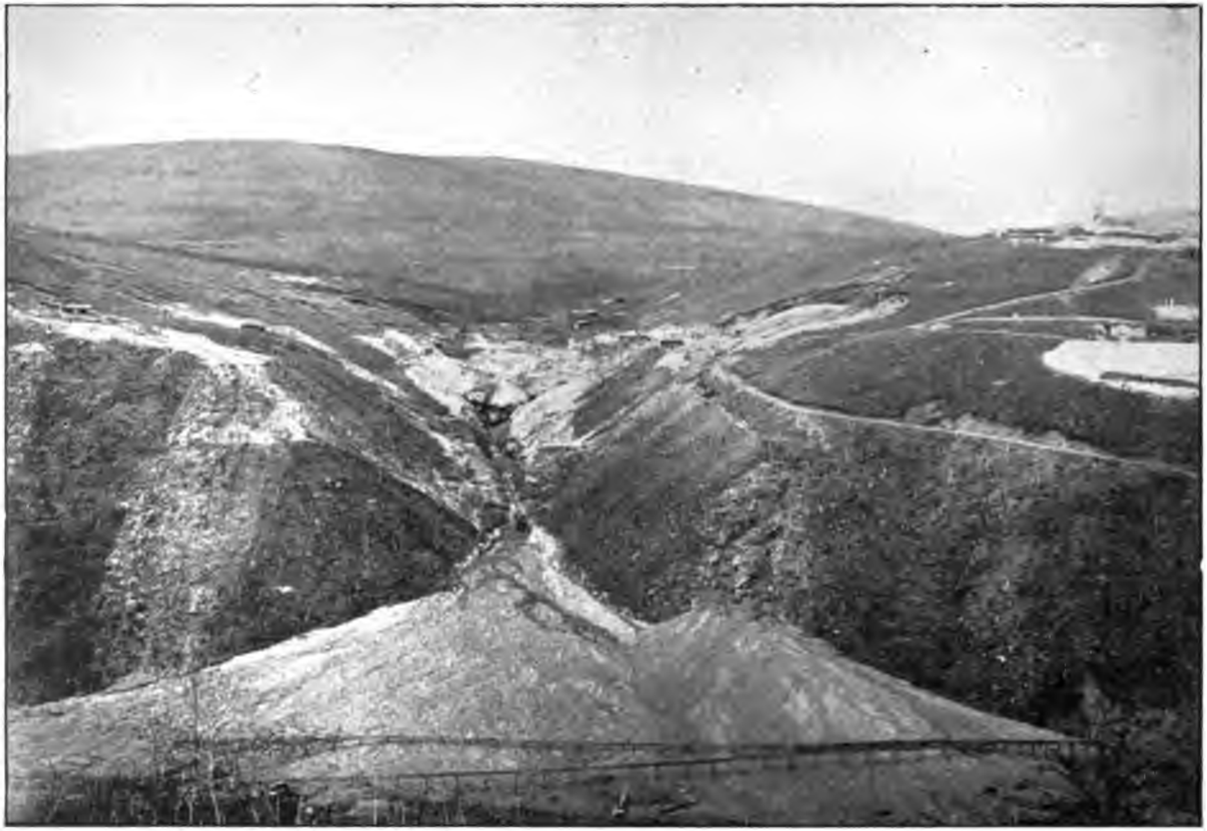
Unlike the creek gravels, the white channel gravels are destitute, or nearly so, of vegetable and animal remains. None were found by the writer and the few reported discoveries of fragments of wood and bone by miners are all open to question.

On Dominion creek and its tributaries, Sulphur and Gold-run creeks, white gravels, almost identical in character with the high level white channel gravels of Bonanza and Hunker creeks, occur in the bottoms of the valleys underlying the present stream gravels. Their low position is due to the fact that the present valley of Dominion creek, corresponds, not to the present valley of Bonanza and Hunker creeks, but to the old valleys cut through by them.

Origin of white channel gravels.

The peculiar character of the white gravels has led to considerable diversity of opinion in regard to their origin : they have been attributed to ice, stream, lake and fiord action. In some of the sections, they bear a close resemblance to coarsely stratified till, but no evidences of glaciation have been found in the region. They could not have been deposited in still water, as they occur following steep valleys, heading closely together and running in opposite directions, and they differ from ordinary stream deposits in their compactness, white colouration, and imperfect bedding and differentiation of material.

They are now regarded by the writer, although a different view was formerly entertained, as stream gravels deposited under somewhat peculiar conditions, chief among which was an exceedingly slow accumulation in streams of easy grades and comparatively slack currents. In the present streams, the schist pebbles greatly outnumber those derived from the quartz veins, while in the old streams the proportion is reversed, although both derived their supply from the same hillsides.



FOX GULCH WORKINGS, SHOWING BELL-ROCK SLUICE IN CREEK BED OF FOX GULCH ; ALSO SHOWING HYDRAULIC GIANT AT WORK ON JOHNSON AND ASKANI CLAIMS.

[p. 32].

The wash of the old streams is thus, in some respects, a residual deposit composed largely of the more resistant constituents originally present, the softer rocks having been eliminated either by abrasion in the bed of the stream or by the slow process of decomposition.

The white channel gravels are much older than the other gravels in the district and probably date back to the Pleocene at least. They were almost certainly deposited when milder climatic conditions than at present prevailed, as the leaching out of the greater part of the iron, and the decayed condition of the schist pebbles must be attributed to surface waters, and no circulation of these was possible if the gravels, like those in the present streams, had been frozen together as soon as deposited.

DESCRIPTION OF CREEKS.

Gold Bearing Creeks Tributary to the Klondike River.

BONANZA CREEK.

Character of Bonanza creek.

Bonanza creek is the most important of the gold-bearing creeks of the Klondike district, and is the one on which gold in large quantities was first discovered. It heads in the Dome ridge with branches of Quartz and Hunker creeks and empties into the Klondike river three quarters of a mile above Dawson, after a course in a N.W.N. direction of a little over seventen miles. It has a drainage area of approximately 113 miles. It is a comparatively small stream even near its mouth, where it measures, in ordinary stages of the water, about fifteen feet in width by three or four inches in depth on the bars. It flows, however, a steady stream and seldom furnishes less than one sluice head of water throughout the season, all along the productive part of the valley. The principal tributaries are Eldorado creek, Adams creek, Boulder creek, Forty-nine creek, Sourdough gulch on the left, and Carmacks fork, Homestake creek, Gauvin creek, Queen gulch and Mosquito creek on the right.

Bonanza creek valley.

The valley of Bonanza creek is characterized chiefly by its markedly angular trough- like shape. The present valley has been cut down in the floor of an older valley and that rapidly and almost continuously, as shown by the steep lateral walls and the absence of continuous lines of terraces in the newer valley. The present valley usually shows a flat bottom of varying width commonly measuring from 300 to 600 feet, bounded by steep sides 150 feet high at the Eldorado forks, and gradually increasing in elevation down the valley, or, with a steep wall of the same height on one side and an easier slope on the other. It follows a sinuous line bending with short curves round points that project alternately from either side. The present valley is excavated, as a rule, along one side of an older and much wider valley, and the general effect produced is asymmetrical. On one side the slope is broken, at an elevation, usually, of from 200 to 300 feet, by a rough plain of irregular size, but often a third of a mile wide, beyond which is an easy ascent of a thousand feet or more to the summit of a bordering ridge, while, on the other side, the slope, though varying in steepness, is continuous throughout.

The plain of the older valley is not noticeable in the upper part of the present valley, but becomes a marked feature at McKay creek, three miles above the mouth of Eldorado creek, and is then traceable along the right bank down to the Eldorado forks. At the forks it crosses to the left and follows the left bank to Sourdough gulch, then re-crosses and continues on down the right side to the point of the ridge separating Bonanza creek from the Klondike river. Above McKay creek, the slopes of the valley become more uniform, but continue, for some distance, steeper on the left side than on the right.

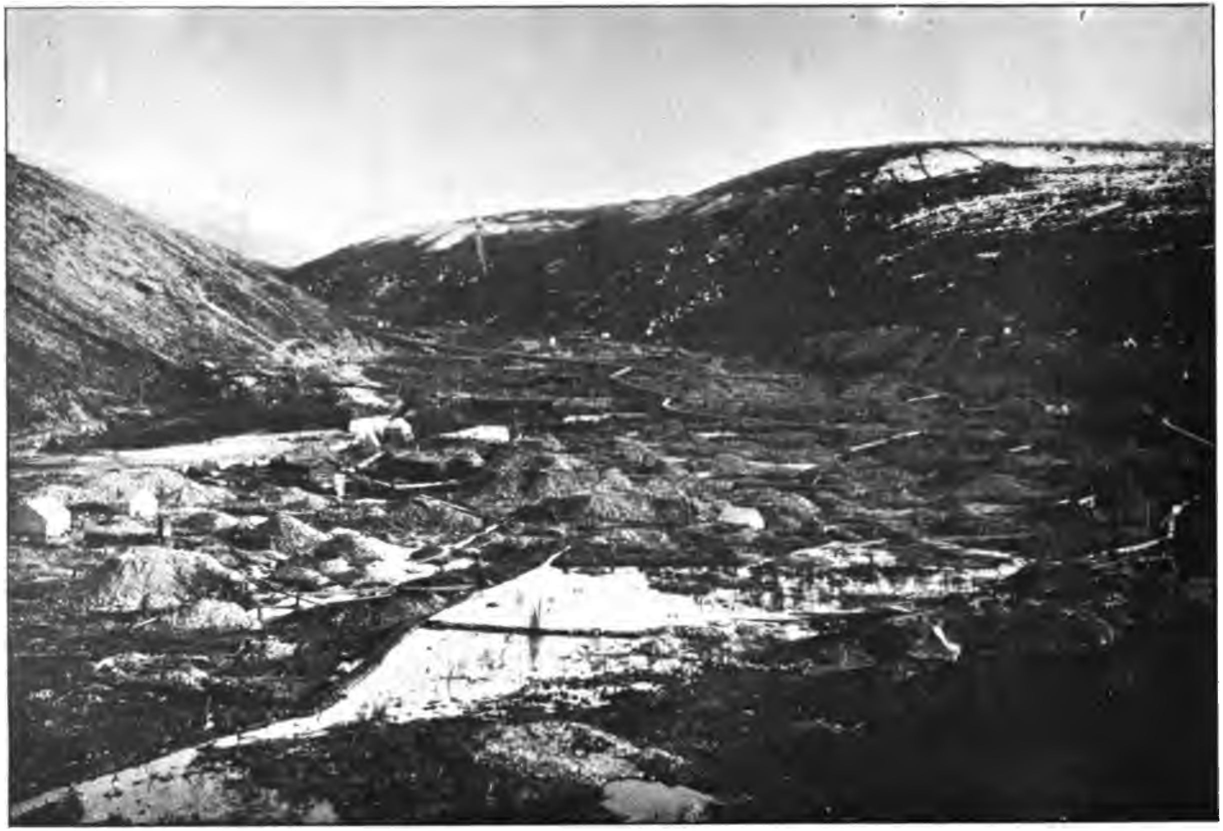
Grades.

The grade of the older valley is less than that of the modern one. The rim of the older valley at McKay gulch is 110 feet above the present valley-bottom; at the forks it is 150 feet and at the mouth its elevation is increased to about 300 feet. The grade of the present valley below the forks averages about fifty feet to the mile, and that of the older valley thirty-three feet to the mile. Between Eldorado forks and the Carmack forks, the grade of the present channel averages one hundred feet to the mile and further up increases rapidly. Besides the plain of the older Bonanza valley, a number of more recent terraces occur at lower elevations. These terraces are rock-cut as a rule, are usually quite narrow, are only traceable for short distances, and recur at irregular distances. They are found at intervals all the way from Lovett gulch up to Victoria gulch.

Rocks along valley.

Country Rocks.—The rocks along Bonanza creek consist almost entirely of the light-grayish and greenish sericite schists of the Klondike series, alternating in the upper parts with bands of green chloritic schists. Narrow bands of dark graphite schists cross the valley above the mouth of Adams creek and at one or two other points. The sericite schists are often silicified and inclose numerous small quartz veins.

Gravels.—All the gravels enumerated on page 29 are represented on Bonanza creek. In order of economic importance the present valley gravels come first, then the high level white gravels, followed by the terrace gravels. The high level river gravels and the yellow gravels have not proved productive.



BIRDSEYE VIEW OF BONANZA, LOOKING UP FROM 46 "BELOW."

[p. 34.]

Description of gravels.

The valley gravels consist of clean, flat, fairly well-worn pebbles, mostly from one to six inches in length and one to two inches in thickness, derived from the light-grayish and light-greenish micaceous schists of the neighbourhood, associated with rounded and subangular pebbles of quartz and, occasionally, large quartz boulders usually angular in form. A few pebbles of dike-rock are generally present. The material is wholly of local origin and is derived from the rocks outcropping along the valley. The pebbles are roughly shingled up stream, lie in a matrix of coarse sand and are occasionally interstratified, especially above, with beds of sand. They rest on the floor of broken and decomposed bedrock, into which the gold has often penetrated to a depth of three or four feet. The gravels form a fairly uniform covering of from four to eight feet in thickness all across the flat bottom of the valley. Their width varies with the enlargements and constrictions of the valley, but usually measures from 300 to 600 feet, with occasional enlargements to 900 feet or more. The width increases gradually but irregularly down the valley.

Muck.

They are overlaid everywhere by a bed of black frozen muck from five to fifteen feet in thickness. The muck occurs in most places in a massive bed, but is also found interbanded with layers of sand. Small beds of impure muck occur in places alternating with the gravels almost down to bedrock.

The terrace gravels have a general resemblance to the stream gravels. They are formed of the same materials, but the pebbles show, as a rule, more wear. They are roughly stratified and include beds of small pebbles and sand, often showing cross-bedding. The terrace gravels have a limited distribution. They rest on short, narrow rock-shelves distributed irregularly along the valley, on flat projecting points; or are built up at the mouths of gulches and streams. They are uncovered at some points, and, in other places, are deeply buried beneath an accumulation of muck and rocky *débris* from the sides of the valley.

White gravels

The white gravels, which, with the associated yellow gravels, floor the older and more elevated Bonanza valley, have been described generally on a previous page. This unique and important deposit is extensively, but not continuously, distributed along Bonanza creek. It is necessarily absent where the ancient and modern valleys coincide, and has also been swept away in other places by erosion. It is found descending the creek, covering small areas below McKay creek and Homestake creek and a much larger area below Gauvin gulch. At the latter place it rests on a nearly level rock floor at an elevation of about 140 feet above the present valley-bottom. It occurs uncovered along the edge of the valley, but farther back is buried beneath an accumulation of loosely stratified gravels and sand. The total width of both deposits at this point measures approximately 2,000 feet and the depth ninety feet. A shaft sunk to bedrock, 450 feet back from the rim, showed fifty-five feet of the loose upper gravels and thirty feet of the compact white gravels. The gravels of the old valley extend from Gauvin gulch down Bonanza creek almost to Eldorado forks, but the upper gravels only are present along part of this distance, and are also traceable in a narrow disconnected band up Gauvin gulch for a considerable distance at an elevation of about 100 feet above the valley-bottom.

At Eldorado forks, the plain of the old valley crosses to the left side of Bonanza creek. A small patch of gravel has been left on the point of the ridge separating the two creeks, and, immediately opposite the forks and extending for some distance up Eldorado creek and down Bonanza creek to Big Skookum gulch, is the important Gold hill deposit. The gravels here cover an area about half a mile in length by 2,000 feet in width and have a maximum thickness of about 116 feet. The white gravels outcrop at an elevation of 150 feet above the bottom of the valley and appear, so far as one can judge by the shafts, to form a great ridge following the edge of the valley, a hundred feet or more in height and 500 to 600 feet in width, with the hollow behind filled up with the yellow gravels. The rock surface on which the gravels rest is roughened with small hollows and ridges. It extends back from the river at nearly the same general elevation for several hundred yards; then it rises somewhat abruptly to the surface.

The white gravels are absent between Big Skookum and Little Skookum gulches but come in again below the latter on Adams hill and continue to Adams creek. The gravels on Adams hill have a width of 2,000 feet and a depth, 550 feet back from the rim, of 130 feet. The arrangement of the white and yellow gravels is similar to that on Gold hill. Below the break formed by the valley of Adams creek, high level gravels occur pretty constantly, except where cut away by gulches, all the way down to Fortynine creek; and at one point below Mosquito creek they cross the valley and appear in a band 450 feet wide and ten to twenty feet in thickness on the right hand side. The thickness of the deposit on the left limit often exceeds 125 feet. The width is variable but usually measures from 1,200 to 2,000 feet.

Below Fortynine creek, the deposit becomes less continuous for some distance. A small patch occurs below the mouth of Fortynine creek; a second opposite claim 57 below discovery; and another, the last, on the left limit below Sourdough gulch. At the latter point it crosses the valley to the right limit above Cripple creek and continues down, gradually increasing in width, past Trail and Lovett gulches and across the plateau in which the ridge separating Bonanza creek from the Klondike river terminates, to the valley of the latter. The volume of the deposit becomes greatly increased after crossing the valley. Its thickness on the hill between Trail and Cripple creeks is 225 feet, and on Lovett gulch is not less than 150 feet. The width, near the mouth of the valley, is over half a mile.

River gravels.

High level river gravels occur on both sides of Bonanza creek near its mouth. On the right limit they rest on the white channel gravels and on the left limit on rock benches. They have a thickness of from 150 to 200 feet and are found up to an elevation of 700 feet above its present valley-bottom. No gravels of any kind were found above this level. The high level river gravels differ from the creek gravels in being well-rounded and in consisting of foreign material, principally slate, quartzite, diabase, etc., mostly obtained from the sources of the Klondike river.

Gold in creek gravels.

Gold contents of gravels.—The creek gravels of Bonanza valley have proved productive from Victoria gulch down to the mouth of the creek, a distance of about thirteen miles. The gold is distributed along the creek in a somewhat erratic manner. No claims have been worked at a profit from the head of the creek down to claim No. 43 above Discovery, at the mouth of Victoria gulch. No. 43 and the succeeding six claims going down stream, were good producers, and the ten claims following, Nos. 36 to 25, all proved remarkably rich. Some of these 500 foot claims have yielded upwards of half a million dollars each, or at the rate of over $1,000 per running foot of valley. The gold tenor of the gravels decreases approaching Eldorado forks, but increases again below the forks. A short stretch of the creek above Discovery claim, half a mile in length, was exceedingly rich and in spots almost fabulously so. A fraction at the mouth of Little Skookum gulch, about eighty feet in length, commonly known as Dick Low's fraction, is reported to have yielded over $300,000. The claims below Discovery down into the fifties all yield well. In the lower part of the creek, the gold in the gravels becomes finer and less plentiful, but there are few claims, if any, right down to the mouth of the creek, which cannot be worked at a profit under present conditions.

The Bonanza creek stream gravels, below Victoria gulch, are seldom entirely barren, and along the more productive portions of the creek have been worked from rim to rim across the whole width of the valley-bottom. The values are irregular but are not confined to one particular pay-streak, and are usually largely dependent on the condition of the bedrock. Where this is smooth and soft, the gold slips along it, and is collected where the harder schists form natural riffles. The gold occurs both in the gravel and in the underlying shattered bedrock. From two to four feet of bedrock are usually mined and washed and from four to six feet of gravel.

Gold in white channel gravels.

The white channel gravels are scarcely inferior in economic importance to the creek gravels. Claims of varying richness, often several tiers deep, have been staked on this deposit wherever it occurs, all the way from McKay gulch down to the lower end of the valley. The most productive part extends from Eldorado forks down stream to Boulder creek, a distance of three miles. In this stretch, a pay-streak nearly 1,000 feet in width in places, has paid to work by methods entailing an expenditure of from four to six dollars per cubic yard of material mined. In the early days of the camp, when rocking was the only means of working the gravel, the cost was even greater. In the richest places whole claims are reported to have yielded over sixty dollars per superficial yard, while values of from twenty to forty dollars per square yard of surface were common. In the lower part of the valley the values are less, but claims have been staked and worked at a profit as far down as Lovett gulch.

Distribution of gold.

The distribution of the gold in the white channel gravel follows the usual rule in creek gravels. It is mostly concentrated in the lower three to five feet of gravel and the underlying one to two feet of bedrock. The bedrock, while more decomposed, is not shattered so badly as in the present creek channel, and the gold has not descended so far. The upper surface of the pay gravel is irregular, and in some instances the pay has been followed upward eight to ten feet or more above bedrock. In places where the bedrock is uneven, the gravels on the summits of the wavy elevations usually carry greater values than those in the depressions.

While the greater part of the gold in the white channel gravels is found close to bedrock, the deposit carries some values throughout and it is this fact which gives it such great importance in view of future hydraulicing operations. Less than half per cent of the total volume of the deposit, estimated at 250,000,000 cubic yards on Bonanza creek alone, has been worked or is workable by the drifting method.

The terrace gravels of Bonanza creek yielded well while they lasted, but occurred in small deposits and were soon exhausted. The yellow gravels associated with the white gravels and the high level river gravels have not proved remunerative with present methods.

Bonanza creek gold.

Character of gold.—Bonanza creek gold occurs in coarse, rough, usually flatish grains in the upper part of the creek and in similar but smaller scales in the lower part. Nuggets are obtained occasionally from most of the claims but are not plentiful, except near the mouth of little Skookum creek. They are small, as a rule, seldom exceeding half an ounce in weight, and no very large ones have been found. The nuggets are often crystalline in character and nearly always inclose grains and fragments of quartz. The value of the gold above Eldorado creek averages about $16.75 per ounce. Below Eldorado creek, the value drops to about $16.00 per ounce and in the lower part of the creek is about $16.25 per ounce. The gold in the white channel gravel is lighter in colour than in the creek gravels, is slightly lower in grade and is more angular and include, a larger proportion of nuggets.

Bonanza creek tributaries.

The tributaries of Bonanza may be separated into creeks occupying flat-bottomed valleys and those in V-shaped gulches. None of the larger creeks, with the exception of Eldorado creek, which is described separately, have yielded much gold. Adams creek enters Bonanza creek a mile below Eldorado creek on the same side. It is nearly equal in size to Eldorado creek, cuts the same rocks, and its valley is almost precisely similar in general character, yet one creek ranks among the greatest producers ever discovered, while the others have yielded only insignificant amounts. A few claims have been worked on Adams creek below the mouth of Stampede gulch, and some gold has been taken out, but no continuous pay-streak has been discovered. Boulder creek, two miles below Adams creek, is also similarly barren except for a short distance near its mouth. In upper Bonanza, Gauvin and Homestake creeks are both worked to some extent for a couple of miles above their mouths. The plain of the old valley extends up the former nearly to its head, and carries pay gravels in places.

Gulches.

Among the more important Bonanza gulches are Victoria, O'Neil and Ready Bullion, on upper Bonanza; Big Skookum, Magnet, American, Fox, Monte Christo and Lovett gulches on lower Bonanza.

Victoria gulch, the most productive of the upper Bonanza gulches, enters Bonanza creek from the left, one and three quarter miles below

Carmacks fork and almost at the head of the productive part of the creek. It heads with Gay gulch, a gold bearing tributary of Eldorado creek. It is about two miles in length and, in character, conforms strictly to the gulch type. At the head is a steep regular amphitheatrical depression leading into a narrow angular valley that gradually enlarges down stream. It has a fall of about nine hundred feet. The narrow gutter-like bottom of the valley is covered with from two to seven feet of coarse angular gravel and slide rock, overlaid by a few feet of muck. The gold from this gulch is coarse, and in the upper part was exceedingly rough and angular, and looking as if it had just dropped out of crevices in the quartz.

A small tributary of Victoria gulch, known as No. 7 pup, has also been found gold bearing for a distance of half a mile above its mouth. It joins Victoria gulch on No. 7 claim and is simply a shallow depression in the hillside. It has a steep grade rising four hundred feet in the first seventeen hundred feet of its course. The gravel is angular and consists principally of almost unworn slide rock. The gold is also coarse and angular and includes some large nuggets. A flat, oblong, unworn nugget, found on No. 7 claim, weighed four and a half ounces.

Ready Bullion and O'Neil gulches are similar in character to Victoria gulch. Both yielded small amounts of gold.

The productive lower Bonanza gulches, between Adams and Boulder creeks, differ in some respects from those just described. They cut through the white channel gravels and have not proved productive, beyond the edge of this deposit. The rich claims near their mouths have evidently derived their supply of gold from the older gravels and not from original sources. Big Skookum gulch, above Adams creek, was similarly enriched near its mouth with gold concentrated from the white channel gravels, but a few claims near its head also contain coarse angular gulch gold.

ELDORADO CREEK.

Character of Eldorada creek.

Eldorado creek, the most important tributary of the Bonanza creek, is a small stream about seven miles in length and from three to six feet in width at its mouth. It carries, late in the season, barely a sluice head of water. The valley is flat-bottomed for three or four miles above its mouth, but narrow, the flats seldom exceeding 300 feet in width. The present valley is excavated, like Bonanza creek (of which it is a continuation) in an older and wider one. It shows the same characteristics as Bonanza valley, having a trough-like depression below, 150 feet deep and from 225 to 450 feet in width, above which the slope is continuous and fairly steep to the summit of the ridge on the right limit, but on the left is interrupted by the plain of the old valley, usually about a quarter of a mile in width. Beyond the plain the upward slope recommences, but at a lower angle. The plain of the old valley follows the left bank of Eldorado creek for two miles above its mouth. Above this it follows the rightbank to a point above Oro Grande gulch, where it disappears. The upper part of the valley, from Chief gulch upward, is narrow, steep and V-shaped. Narrow terraces occur at intervals in the lower part of the valley, but do not form a conspicuous feature.

Country rocks.—A few narrow diabase dikes cross the lower part of Eldorado creek, and narrow bands of dark graphitic schists were noticed in one or two places, but with these exceptions the valley is cut altogether out of the light-coloured micaceous schists on the Klondike series. Quartz veins are everywhere present, some carrying free gold.

Gravels.—The Eldorado creek gravels are precisely similar to those on Bonanza creek. They consist of from five to nine feet of flat schistose, and angular or rounded quartz, pebbles, covering the bottom of the valley in a fairly uniform sheet, overlain by a few feet of frozen muck.

White channel gravels.

The white channel gravels have an elevation above the present valley bottom, at the mouth of the creek, of 150 feet, and three miles farther up, where they disappear, of 125 feet. They consist, as on Bonanza creek, of a white compact deposit below and an upper series of stratified flat pebbles overlying these. Areas of white gravels occur at the mouth of Eldorado creek, forming part of the Gold hill deposit previously described, and on French hill, immediately below French gulch, while smaller patches occur about half a mile below French gulch on the same side, and half a mile below Gay gulch on the right limit. At the latter point, the deposit occurs for the last time ascending the creek. It is quite narrow and has a thickness of only eighteen feet. It lies in a shallow-pitted channel-like depression running parallel to the present valley. At French hill it has a thickness, including the upper gravels, of over a hundred feet. The occurrences between French hill and Gold hill are small and unimportant.

Gold production.

Gold contents of gravels.—Eldorado creek has proved the richest creek in the Klondike district and one of the greatest placer creeks ever discovered. The claims are numbered from the mouth up, and are approximately 500 feet in length. The first thirty-seven claims, with a few intervening fractions, have yielded gold of an estimated value of between twenty and twenty-five million dollars and several millions will be added to this amount before the creek is exhausted. The most productive portion of the creek extends from its mouth up the Gay gulch, a distance of about three and a half miles. The gravels on this stretch, with the exception of those on claims 34 and 35 and on claims 18 to 21, were all extraordinarily rich. No. 17, at the mouth of French gulch, reputed to be the richest claim in the whole district, has yielded nearly a million and a half dollars worth of gold, and claims Nos. 5, 16 and 30 almost rival it in importance. Above Gay gulch the gold in the gravels diminshes in quantity and is more erratic in its distribution, but mining has been done up to the mouth of Chief gulch and a narrow pay-streak, carrying values in places, has been traced for some distance beyond. The pay gravels of Eldorado creek, like those on the greater part of Bonanza creek, extend, although the values vary somewhat, across the whole width of the valley-bottom. They are shallow, seldom exceeding four to six feet in thickness. A considerable proportion of the gold occurs in the partings of the underlying schistose bedrock and from two to four feet of this is usually mined and washed. Terrace gravels, often moderately rich, occur along the valley at intervals from Gay gulch down to the mouth.

Rich claims.

Continuation of pay.

The white channel gravels are less important than on Bonanza creek. Part of the rich Gold hill occurrence of this deposit, previously described, extends up the valley of Eldorado creek. A number of the claims on French hill also proved very rich and fair results have been returned from the occurrence above Oro Grande gulch.

Character of gold.

Eldorado gold is very coarse and is often angular and almost unworn. Nuggets are more plentiful than on the other creek, and are often crystalline in form. Several nuggets, valued at from $400 to $1,000, have been obtained from the upper part of the pay streak. The gold is lighter in colour and of a somewhat lower grade than on Bonanza creek, the assay value usually varying from $15.50 to $15.75 per ounce.

Tributaries of the Eldorado.—The tributaries of Eldorado creek, like those of Bonanza creek, are comparatively unimportant. Some gold has been obtained from Gay gulch, Nugget gulch, the lower part of French gulch, and from claim No. 6, on Chief gulch. The gulches are steep, and most of the gold received by them from the hillsides has been carried down into the main valley.

HUNKER CREEK.

Character of Hunker creek.

Hunker creek is a tributary of the Klondike, into which it empties, six miles above the mouth of Bonanza. It heads close to the Dome, with Dominion creek, and flows in a north-westerly direction. It has a length of fifteen miles, and is about equal in size to Bonanza creek. The most important tributaries are Last Chance and Goldbottom creeks, both of which come in from the left.

Valley.—The valley of Hunker creek is remarkably similar to that of Bonanza creek, and, like it, its present form is due to a secondary valley sunk in the floor of an older one. The recent valley, near its mouth, is sunk through 100 feet of gravel and 300 feet of bedrock. It is a steep-sided, flat-bottomed trough, two to four hundred yards wide near the mouth, but gradually narrowing up stream. Its width is more irregular than Bonanza valley, and the basins developed at intervals in the lower part are wider. The plain of the old valley is a marked feature from the mouth up to a point a mile above Goldbottom creek, a distance of eight miles. It disappears there, but comes in again for a short distance a mile and a half farther up.

A few rock-cut terraces occur below the plain of the old valley, but are seldom very conspicuous. Like those on Bonanza creek, they are narrow, irregular in height, and usually quite short.

Geology.

Country Rocks.—The rocks along the upper part of Hunker creek consist of the light coloured sericite schists and the greenish chlorite schists of the Klondike series, cut in places by small areas of recent volcanic rocks, principally andesites and quartz porphyries. From Colorado creek down nearly to Henry gulch, the dark quartz-mica schists of the Nasina series occur most frequently. An area of Tertiary sedimentary rocks, associated with andesite, outcrops at the mouth of Last Chance creek. Above Henry gulch, the rocks of the Klondike series reappear and continue to the mouth of the creek.

Description of gravels.

Gravels.—The gravels on Hunker creek, like those on Bonanza creek, are of four different kinds, viz., the present creek gravels, the terrace gravels, the white channel gravels and a sheet of high level river gravels overlying the white channel gravels near the mouth of the valley.

The creek gravels are all local in origin, and are similar in character to the Bonanza creek gravels. They consist of flat schistose gravels, subangular quartz pebbles and boulders, and occasional pebbles derived from the newer eruptive rocks. They have a thickness of from four to ten feet, and are overlain by from five to twenty feet of muck or peaty material. At Discovery claim, the thickness of both muck and gravel is, for a short distance, less than ten feet.

The terrace gravels are more rounded than the creek gravels, but are otherwise very similar. They occur in narrow, disconnected strips along both sides of the valley, at various elevations up to 200 feet above the present valley-bottom. They have a maximum thickness, in the sections examined, of seventeen feet, and, in places, are of considerable economic importance.

Distribution of white channel gravels.

The white channel gravels have a wider distribution along Hunker creek than on any other creek in the district. They commence, descending the valley, in a comparatively thin narrow band on the right limit opposite number four below Discovery, where they occupy a basin-shaped depression on both sides of number six gulch. They are absent below this point for some distance, but reappear on the left limit half a mile above Goldbottom creek, and continue down on the same side, except when broken through by the valleys of the larger tributaries, to Henry gulch, near the mouth of the valley. A few small patches also occur on the right limit between Goldbottom and Hester creeks. Below Last Chance creek the main deposit crosses Hunker valley and continues through in a wide band to the Klondike valley.

The character of the white channel gravels on Hunker Creek is very similar to that on Bonanza creek. Where typically developed they form a grayish, almost white, compact deposit, consisting mainly of sericite, clear angular quartz grains, quartz pebbles and boulders and a few schist pebbles and boulders. They are also overlain in places as on Bonanza creek, by a yellowish, loosely stratified deposit of flat pebbles derived mostly from the Klondike schists. The thickness of the white channel gravels, between Goldbottom and Last Chance creeks, ranges from 20 to 100 feet and the width from 500 to 2000 feet. Below Last Chance creek they have a thickness of over 100 feet and a width of nearly a mile.

On Paradise hill, below the mouth of Hester creek, the white channel gravels show some modifications. The lower gravels here, as shown in a couple of shafts, consist almost entirely of well-rolled quartz pebbles and boulders embedded in the usual white, fine-grained quartz sericite matrix. These quartz gravels are barren or nearly so, but are overlaid by auriferous beds consisting partly of schist and partly of quartz pebbles. The two gravels are distinctly different in character, and the abrupt passage from one to the other apparently indicates a break in deposition.

The high level river gravels are confined to the lower part of the valley where they overly the white channel gravels, on a small plateau separating Hunker creek from the Klondike above their junction. They also occur on the left limit resting on a rock-cut terrace.

Producing claim.

Gold contents of gravels.—Pay gravels occur along Hunker creek from Claim No. 46 above Discovery on the right fork, down to the mouth of the valley, a distance of over twelve miles. A stretch of the creek about a mile in length, including Discovery claim and a few claims above and below it, proved very rich, the yield in places amounting to $1000 per running foot of valley. Another long stretch of almost continuously rich gravel extends from the mouth of Goldbottom down stream a distance of a mile and a half. Good pay has also been found at a number of points below this, notably on claim No. 71 below Discovery, and near the mouth of Henry gulch, on what is known as the Anderson concession. On claim No 71 the gold has mostly sunk down into the bedrock, consisting here of broken andesite, and the overlying gravels are almost barren.

Value of white channel gravels.

The white channel gravels have not proved so rich as on Bonanza creek, but a number of claims yielding good values have been worked for some distance above and below Goldbottom creek, on Paradise hill, below Hester creek, and on Last Chance creek and Dago gulch. On Paradise hill the gravels on bedrock are barren, and the gold occurs in an upper layer six to ten feet in thickness. The scarcity of water on the hill sides has seriously interfered with the working of the high level gravels of Hunker creek, and the greater part of the deposit is too low grade to bear the expense of pumping water for sluicing purposes.

Hunker creek gold occurs in bulky rounded grains along the upper narrow portion of the valley in the usual rough flattish grains and scales farther down. Nuggets are fairly numerous in the rich stretch near Discovery claim and also in some of the claims below Goldbottom. They are occasionally found as far down as Henry gulch. The gold from about claim No. 45 to No. 59 below is generally darkened on the surface by iron. The assay value of Hunker creek gold averages about $17.25 per ounce above Goldbottom, and from $16.50 to $17.00 per ounce for some distance below. On the Anderson concession, near the lower part of the valley, the grade is lower, some of it averaging less than $15.00 per ounce.

Hunker creek tributaries.

The two principal gold bearing tributaries of Hunker creek are Goldbottom and Last Chance creeks. Goldbottom creek is almost equal in size to the main stream at their confluence, and has a length of about six miles. It carries gold almost to its head, but the distribution of values is irregular and no very rich claims have been found. The best ground occurs near its mouth.

Last Chance creek, a stream about six miles in length, enters Hunker creek from the left near the lower end of its valley. It is gold bearing up to the forks, a distance of four miles, and a number of the claims, especially in the first mile, have proved highly profitable. The white channel gravels follow the left limit up to No. 15 pup, a distance of two and a half miles, and are fairly rich in places. The gold obtained from the upper part of this occurrence is noted for its crystallized character. Last Chance gold is low grade, usually assaying from $14.50 to $15.00 per ounce.

Other tributaries of Hunker creek that have been worked to some extent are Mint gulch, Hester creek, Eighty pup, Henry and Dago gulches, on the left limit, and Hattie gulch on the right limit. With the exception of Mint gulch, the gold in these small gulches has mostly been derived from the white channel gravels.

BEAR CREEK.

Character of Bear creek.

Bear creek empties into the Klondike two miles below Hunker creek. It is a much smaller and less important stream than Hunker and Bonanza creeks. It has a length, including Lindow creek, of about five miles, and occupies a narrow-bottomed box-shaped valley, which gradually narrows to a gulch towards its head. Bear creek has not proved particularly rich, although some good claims have been worked near its mouth, and moderate pay is found almost up to the head of Lindow creek. The gold is low grade, usually assaying less than $15.00 per ounce.

The plain of the old valley is conspicuous along the left limit of Bear creek up to Discovery pup. A small patch of the white channel gravels occurs opposite Discovery pup at a height of 350 feet above the present valley-bottom. The deposit here has a thickness of eighteen feet and is less compact than usual. It carries pay values in places.

ALLGOLD CREEK.

Character of Allgold creek.

Allgold creek heads with Dominion and Hunker creeks near the Dome, but flows in the opposite direction toward the flat creek depression and is the only creek draining the eastern and north-eastern slops of the Klondike hills on which gold in paying quantities has so far been discovered. It was staked during the early days and a few holes were sunk to bedrock, but as no particularly rich spots were found, the claims were all, or nearly all, abandoned. They have been re-staked during the last two seasons and pay gravels have been found at a number of points. The longest pay stretch so far discovered occurs near the mouth of the creek, where several consecutive claims are being worked. The pay is light, none of the claims yielding much more than good wages.

The elevated white channel gravels occur in considerable volume on the left limit of Allgold creek, along the lower portion of the valley, and are overlaid, as usual, near the mouth of the creek, by rounded high level river gravels. They rest on a rock bench of varying width cut into the side of the valley at an elevation of from 150 to 250 feet above the present creek bottom, the elevation increasing down stream. The Allgold white channel gravels have not so far yielded gold in paying quantities, but practically no work has been done on them, owing to the scarcity of water for sluicing purposes.

Allgold creek gold is high grade, having an assay value of about $17.75 per ounce.

GOLD BEARING STREAMS TRIBUTARY TO INDIAN RIVER.

DOMINION CREEK.

Dominion creek.

Dominion creek is the largest and one of the most important of the gold-bearing creeks of this district. It heads the Hunker creek near the Dome, and flows at first in an easterly direction, but gradually bends round to the south and then to the west before uniting with Australia creek to form the Indian river. Its length, following the valley round its semi-circular course, is about thirty miles. The principal tributaries are Caribou, Portland, Laura, Hunter, Gold-run and Sulphur creeks from the right, and Lombard, Remington, Champion, Nevada, Jansen, Kentucky, and Rob Roy from the left.

Valley.—Dominion creek valley heads in a steep amphitheatrical depression, very regular in form, cut into the divide between Dominion and Hunker creeks. Lower down a deep narrow valley is developed, with steep slopes almost meeting below. Still further down, the bottom slowly widens out; small muck-covered flats, increasing gradually in width, border the winding stream, the grade diminishes and the slopes up to the high, bounding ridges become easier. In the lower part of Dominion creek the flats have an extraordinary width compared to the size of the stream. From Jansen creek to the mouth, they nearly everywhere exceed a third of a mile and, in places, spread out to half a mile or more. The stream itself, at the mouth, has a width of about twenty-five feet with an average depth, on the bars, of about a foot.

Terraces have been traced along the left limit of Dominion creek from Lombard creek to about two miles below Jansen creek. They also occur along the lower part of the valley, but at wider intervals. The terraces are low, seldom exceeding forty feet in height, and in some cases are less than ten feet above the valley-bottom. They are wider than the Bonanza terraces.

Dominion creek differs from Bonanza creek and other creeks extending along the Klondike in not possessing a well marked secondary valley. The present valley-bottom below Burnham creek is supposed to represent the elevated benches that border the Klondike streams. The reason for this is discussed in the description of the gravels.

Geology.

Country rocks —The rocks of Dominion creek have a greater variety than on the other creeks in the district. The upper part of the valley is cut through the grayish sericite schists of the Klondike series, alternating with bands of greenish chloritic schist. The latter is fairly massive in places, and is often filled with grains of pyrite and magnetite. In the central part of the creek, the Klondike schists are largely replaced by biotite-bearing schists, greenish schists and hard quartzose schists. Bands of dark graphite schists are also present, and limestones were found in the right bank opposite claim No. 123 below Discovery. These rocks resemble the schists on Indian river, and are referred to the Nasina series. The schists of the Klondike series come in again below Burnham creek, and are exposed down to a point midway between Gold-run and Sulphur creeks, where they are replaced by sheared granites, and these continue down to the mouth of the creek.

Classification of gravels.

Gravels.—The auriferous gravels of Dominion creek consist of yellowish creek gravels, white creek gravels underlying these, and terrace gravels.

The creek gravels are altogether of local origin and are formed from the rocks outcropping along the valley. They are similar to those in the valleys previously described. Between the two Discoveries, the country rock is unusually soft, and the pebbles are consequently small.

were carried on around the rim where the gravels are thin, and the tailings easily disposed of. When the deeper portions of the deposit are attacked the cost per square yard of surface will necessarily be greater. The increased cost may, however, be compensated for by the greater amount of gold recovered, as it is known that the gravels contain some values throughout.

The demonstration by Mr. Coffey of the feasibility of hydraulicing successfully the frozen hill gravels is important, but in the present circumstances can only be taken advantage of to a very limited extent, as the local supply of water is small and intermittent and only obtainable at a few points.

ORIGIN OF THE PLACER GOLD.

Gold derived from quartz veins.

There is little doubt that the Klondike gold, or the greater part of it, at least, is detrital in origin, and has been largely derived from the auriferous quartz veins cutting the older schists and especially the igneous schists of the Klondike series. The veins are small and the number destroyed and concentrated as pebbles and boulders in the valley-bottoms is almost incalculable. The high level white channel gravels have a volume, on Bonanza and Hunker creeks alone, of nearly 500,000,000 cubic yards, and nearly, if not quite, half the whole deposit consists of quartz grains, pebbles and boulders derived from veins. This figure, large as it is, represents only a fraction of the vein material destroyed, as the volume of the white channel gravels was originally at least a third, and possibly a half, greater and a further allowance must be made for the large percentage of quartz ground up and carried away. The total production of the Camp will probably approach $200,000,000 ; the average gold tenor of the quartz was not, therefore, large, and probably did not exceed a few cents to the ton.

The derivation of the placer gold from quartz veins, as pointed out by Spurr in regard to the Fortymile district, is evident from the character of the grains. The greater part of the gold occurs in irregular flattened discs and bulbs very similar, when unworn, to those in the veins. Many of the grains and most of the nuggets inclose quartz, and a few are themselves inclosed in quartz. Pebbles and boulders speck'd with gold are also occasionally found. A boulder from Bonanza creek, near Discovery, weighing sixty ounces, contained twenty ounces of gold. Additional evidence of the detrital origin of the gold is afforded by its worn character in the creeks, while the younger grains and nuggets found in the gulches are always rough and angular. The richest quartz, so far discovered, occurs near the head of Victoria gulch a tributary of Bonanza creek. The partially decomposed slide rock, which covers the surface of the hill side below the quartz outcroppings, contains colours of gold, and it is significient that Bonanza creek is rich below the mouth of Victoria gulch, and practically barren above. Victoria gulch is itself gold-bearing, and the gold obtained from near its head is sharply angular. It is not inferred from this that all the gold in Bonanza creek came from Victoria gulch, as none of the heavy gold has travelled far, and the valley was probably repeatedly enriched from veins along its course, and from the older gravels, but that some of it was so derived seems certain.

Gold deposited from solution.

While the greater part of the placer gold has been derived from broken quartz veins, a small percentage may have been precipitated from water carrying gold in solution, A boulder was found on one of the workings on Miller Creek, the upper surface of which was partially covered with thin specks and scales of crystalline gold. The crystals were arranged in a dendritic manner. Some of them were firmly attached to the rock, and others separated easily from it. The angles of the crystals were sharp and showed no wear of any kind, while the boulder itself, an autoclastic quartz-mica schist, was well-rounded. The gold evidently did not belong to the rock originally, and the only explanation of its occurrence under the peculiar conditions stated seems to be that it was taken up by some solvent and re-deposited on the surface of the boulder. A number of thin specimens of nearly unworn crystalline gold, often dendritic in structure, have been found on Eldorado and other Klondike creeks, and they may have originated in this manner. The bulky, octohedral crystals, (the common crystalline variety) were probably derived, like the nuggets, from veins. Several specimens of these, identical in character with those in the gravels, have been obtained from the Victoria gulch quartz.

QUARTZ VEINS.

Quartz veins abundant.

Quartz veins are exceedingly abundant in the schists of the Klondike series, and also occur, but more sparingly, in the clastic Nasina schists, and in the Moosehide diabase. The veins, as a rule, are small and non-persistent, varying in size from mere threads up to masses of quartz one to two hundred feet in length and from four to six feet in width. Large veins occur occasionally, one on the Yukon river, below the mouth of Cariboo creek, measuring over thirty feet in width.

Character of quartz veins.

The common vein of the district is generally lenticular in outline, the lenticles, in the majority of cases, measuring only a few inches in width, and a few feet in length. The larger veins swell out, in places, to a width of from four to six feet, but are seldom traceable for any considerable distance. They follow the planes of schistosity, as a rule, or cut them at a small angle. In some instances, while the strikes of the vein and the enclosing schist nearly coincided, the dips proved to be in opposite directions. Branching veins are not uncommon, the branches often cutting directly across the schists.

Besides the common lenticular variety, what might be called sheeted veins occur conspicuously in some of the sections, interleaved with the foliæ of the schists. These veins are seldom more than three or four inches, and are usually less than half an inch, in thickness. They differ from the lenticular veins in their more uniform thickness, and in their strict conformity to the inclosing schists, even when the latter are sharply bent.

The quartz veins are usually milk white or light grayish in colour, and, when much weathered, have a granular appearance. They inclose fragments of schist similar to that in the walls, are distinctly crystalline and occasionally show lines of interlocking, flattened quartz crystals. A notable feature of the veins is the presence in them of occasional feldspar crystals indicating a relationship to the pegmatites. A few examples of typical pegmatite veins or dikes occur in the district, and, in one case, a coarse-grained pegmatite vein was observed to pass along its strike into a purely siliceous rock. The aqueo-igneous origin of the pegmatites, and their close genetic connection with certain classes of quartz veins, maintained by various writers, is supported by the facts observed in the Klondike district. In the neighbouring Fortymile district, Spurr has described a transition of similar quartz veins into pegmatites, and through the latter into aplites.

Age of quartz veins.

The lenticular quartz veins are much younger than the schists, and are older than the massive andesites and quartz porphyries. They were probably formed during, or, as a consequence of, the intrusion of the granite mass south of Indian river.

The metallic contents of the quartz veins present little variety. Iron is usually present in the form of pyrites and, less frequently, magnetite, often in sufficient quantities to give the vein a rusty colour when weathered. Copper pyrites and galena, the latter sometimes argentiferous, occur less frequently, and free gold has been found in a number of veins, occasionally in considerable quantities. A short lens of quartz found near the head of Victoria gulch was studded at one end with numerous grains and small nuggets of gold, some of them well crystallized. The gold occurred mostly at or near the surface, very little being found in the interior of the vein. Small veins carrying grains of gold have been discovered on nearly all the producing creeks.

Tin.

Cassiterite (stream tin) has been obtained from the sluice boxes on Hunker, Bonanza and Sulphur creeks, but has not, so far, been found in veins. It occurs in smooth rounded or mammalated pebbles up to an inch in diameter. The presence of osmoridium with Klondike gold has also been detected by Mr. Carmichael of the Department of Mines, Victoria, B.C.

LODE MINING.

Attempts at lode mining.

Lode mining has, so far, made little progress in the Klondike district, although a great number of claims have been staked, and some development work has been done on a few of them. The veins, as already pointed out, are usually small and non-persistent, although they occasionally swell out into considerable lenses of quartz. They often give fair assays, and, in places, show free gold but, except in rare instances, are too small individually to make mines. They occur in great abundance and in some sections constitute a considerable proportion of the whole rock mass. The discovery of a zone of small auriferous quartz veins closely grouped and capable of being worked together is by no means impossible. The region is difficult to prospect, as the slopes of all the ridges are covered with a sheet of partially decomposed slide rock, blanketed in places with moss, and the valley bottoms are buried beneath muck. Bedrock is seldom exposed except along the summits of the ridges and the sides of the secondary valleys.

Victoria gulch veins.

The most interesting group of quartz veins in the district is those referred to before as occurring near the head of Victoria gulch. The development work done on these consists of a few shallow shafts or pits, none of which reach any considerable depth, and a short tunnel. At one of the openings on the New Bonanza claim a short rich kidney of quartz, nearly six feet in width, was uncovered. A second opening, 200 feet to the south-east, has been sunk, following a smaller quartz vein in which no free gold could be detected with the naked eye, or an ordinary magnifying glass. A sample was assayed in the laboratory of the Survey and gave 2,625 ozs. of gold and 3,267 ozs. of silver to the ton. The silicified country rock, mostly sericite schists, adjoining the vein also proved to be auriferous. Other small quartz veins occur in the vicinity, all striking in a N.E. and S.W. direction. The coarse angular gold in Victoria gulch and No. 7 pup must have been obtained from these veins, or from neighbouring ones concealed beneath the surface covering, or wholly destroyed by erosion. Work on them is now temporarily stopped, but the prospects are certainly encouraging and warrant further investigation.

Violet group

A claim in the Violet group, situated on the summit of the ridge separating Eldorado creek from Ophir creek, a tributary of Indian river, was worked during the past season, and is the only claim on which any considerable amount of development was done. The works consist of an open-cut about sixty feet in length, and a couple of shafts. The open-cut follows a quartz vein that swells out, in places, to a width of five or six feet. The vein is broken by several small faults, and follows, at one point, for a few feet, a cross-fracture plane, running at right angles to the general course. It strikes with the inclosing schists in a S.E. direction, but dips across them. A shaft is now being sunk a short distance north of the vein to intercept it in depth. The quartz is crystalline and, like many of the veins in the district, is dotted in places with reddish feldspars giving it a pegmatitic character. It holds a considerable amount of iron and, near the surface, weathers to a rusty colour. Some galena is also present. The gold values are variable, but are stated to average $10.50 to $11.00 per ton.

Claims on Lepine creek.

A large number of claims have been staked on Lepine creek, north of the Klondike river. The claims are staked on a wide band of sericite schist, the ordinary country rock of the district. The schist is often somewhat silicified and, in places, is impregnated with iron. Only one claim, the Great Eastern, was worked during the past season. This claim is situated south of the deep valley of Ruiter creek, a tributary of Lepine creek. The schists here are traversed by a wide dike belonging to the recent quartz-porphyry group, and both schists and dike rock are completely decomposed to a depth of at least fifteen feet. This decomposed material constitutes the ore. A tramway, half a mile in length, has been built, and the ore is trammed down to Ruiter creek, and treated in a small cyanide plant. The result of the season's operations is not known. Specimens of the ore, collected by the writer, and assayed in the laboratory of the Survey, showed only traces of gold.

Auriferous conglomerates.

The Tertiary rocks north of Indian river include large bands of conglomerates, some of which are auriferous, and numerous claims have been staked on them. Very little development work has, so far, been done. At the Britannia claim, situated on McKinnon creek, a few miles south of Indian river, a shaft sixty feet deep has been sunk, and a short tunnel has been driven into the side hill. The shaft penetrates through a peculiar, white, moderately hard conglomerate, discoloured in places with iron. The conglomerate consists mostly of small well-rolled pebbles of vein quartz imbedded in a siliceous matrix. Assays of several dollars to the ton are reported from this conglomerate and a mill test of two tons, at the government stamp-mill, at Dawson, gave $2.24 per ton. The gold is detrital, occurring in the matrix, and the deposit may be considered an ancient placer, probably of beach origin.

The conglomerates in the Tertiary basin are well worth investigating. They were brought down by streams traversing rocks, and by auriferous quartz veins; some gold must almost certainly have been deposited with them, especially near the mouths of the old valleys. Unfortunately, all traces of these have disappeared in the general erosion of the district, and a large amount of expensive exploratory work will be necessary to prove or disprove the existence of pay ore.

PRESENT CONDITION AND FUTURE OF CAMP.

The gold production of the Yukon Territory, since the discovery of the Klondike gold fields in 1896 is estimated by the statistical branch of this Department at over $96,000,000. The annual production has been as follows :—

Gold production of camp.

1896	300,000
1897	2,500,000
1898	10,000,000
1899	16,000,000
1900	22,275,000
1901	18,000,000
1902	14,500,000
1903	12,500,000

Cause of dwindling production.

The whole of this immense amount, with the exception of about $1,000,000 credited to the smaller camps, was obtained from the various Klondike creeks and benches and principally from the Bonanza, Eldorado, Hunker and Dominion creeks, and the Bonanza benches. The dwindling production since 1900, in spite of the increasing use of machinery is largely due to the gradual exhaustion of the phenomenally rich portions of Eldorado and Bonanza creeks, and of the richer Bonanza benches, and does not mark a corresponding decline in the mining industry of the region. The number of creek claims worked, and the amount of gravel handled, has increased, if anything, in recent years, and the decrease in production must be attributed to the lower grade of the gravels mined.

Value of claims.

The centre of mining activity on the various creeks has moved steadily downward towards the wider and leaner gravel beds in the lower portions of the valleys but none of the principal creeks have been abandoned, nor will be for some years yet. Eldorado creek shows the effect of seven years work in an almost continuous line of dumps, from the mouth up to Gay gulch, but even in this rich creek some virgin ground still remains and many old claims are being, or will be, reworked. Claims completely drifted out have a value, on the richer portion of the creek, of from $10,000 to $15,000 each. None are being abandoned, as it is generally believed by the miners that the whole creek from Gay gulch downward will pay to be reworked.

Bonanza-creek has been largely worked over from the head of the pay-streak at Victoria gulch down into the fifties below Discovery. A few claims and a number of partly worked claims still remain, and it is probable that portions of the valley will be reworked. In the lower part of the valley there are still considerable stretches of low and medium grade gravels practically untouched.

Exhausted benches.

The Eldorado and Bonanza benches are rapidly approaching exhaustion, so far as ordinary placer mining is concerned. Very little drifting ground is now left on the rich hills above Adams creek. A considerable amount of work is still being done between Adams and Boulder creeks and also on Lovett and other gulches in the lower part of the valley.

Unworked portions of Hunker and other creeks.

The greater part of Hunker creek, above Goldbottom, has been worked over. A fair proportion of the claims below this point are unworked or only partially worked. Goldbottom, and Last Chance creeks, the two principal gold bearing tributaries, also still possess considerable areas of unworked gravel. Good drifting ground has recently been discovered on the Hunker benches below Hester creek, and further discoveries are probable. The hill gravels are not so high grade as on Bonanza creek and have not been so fully prospected.

Dominion creek is in about the same condition as Hunker creek. The narrow, rich portion of the valley, above Lower Discovery, is largely exhausted, although a few claims are still working. Below Lower Discovery, the proportion of unworked ground rapidly increases. Dominion creek, except on a few benches, has not, up to the present, proved productive between Jansen and Gold-run creek. Discoveries of value in this stretch are possible. Numerous claims are being worked below Gold-run creek, and the large area of gravel already proved to contain moderate pay ensures continued mining activity here for some years.

The short rich pay-streak on Gold-run creek has been partially mined on every claim and, in places, is completely drifted out. Sulphur creek has not been worked so energetically as the richer creeks, and, in consequence, still possesses a considerable number of only partially worked, and unworked claims, and Eureka, Allgold, and Quartz creeks, all comparately low grade creeks, are in a similar condition.

It will be seen, from this brief survey of the condition of the camp, that, while the richer portions of the principal creeks show signs of exhaustion, there still remain considerable stretches of unworked gravel, on all the producing creeks, rich enough to work under present conditions by ordinary placer methods. This industry, therefore, although it is bound to dwindle, will last for a number of years; exactly how long, it is impossible to say, but probably for a decade at least, even if no further important discoveries are made.

Placer mining in the future will, undoubtedly, be supplemented in the Klondike, sooner or later, by hydraulic mining on a large scale. The white channel gravels along Bonanza and Hunker creeks are ideally situated for work by this method, as they rest on comparatively narrow benches, at considerable elevations above the present valleys.

The volume of this deposit cannot be given precisely, but, from such measurements as were taken, is estimated at about 250,000,000 cubic yards on Bonanza and its tributaries, and at about 200,000,000 cubic yards on Hunker creek and its tributaries. About 15,000,000 cubic yards occur on a low bench on Quartz creek, and a smaller quantity on Bear creek. The Allgold creek occurrence of the deposit is extensive, but is lower grade than on the other creeks, and has not, so far, proved rich enough to drift.

Value of deposit.

While the principal values in the white channel gravels are obtained near bedrock, the deposit is auriferous throughout, and it is this fact that gives it such great importance. The cost of mining by the drifting method generally exceeds three dollars per cubic yard, and the proportion of the deposit rich enough to be profitably worked by this method measures less than half per cent of its total volume. The great bulk of the deposit, if worked at all, must therefore be exploited by a much cheaper method.

The small amount of hydraulicing already done has proved the existence of pay in the upper gravels, in places at least, and has also shown that, with a long exposed face, no great difficulty need be apprehended from the frozen condition of the deposit. The great drawback to hydraulicing is the absence of local water in sufficient quantities, and the necessity of bringing it, at great expense, from a distance, or pumping it up from the Klondike river.

WATER SUPPLY.

The Klondike creeks are all small, and the available local supply of water is scarcely sufficient for sluicing purposes, and is quite inadequate under present conditions to furnish the amount required for hydraulicing on a large or even moderate scale. An additional water supply would benefit mining in the creek bottoms, but is chiefly required for the high level gravels, as, without it, only a small proportion of the great volume of these deposits can be worked at all.

The principal schemes proposed for augmenting the present supply include damming the valleys at certain points, and impounding the spring floods, pumping water from the Klondike, and bringing it by gravity from the Klondike and Twelve-Mile rivers or their tributaries.

Damming the valleys.

The plan of damming the valleys, if successfully carried out, would add largely to the present supply, but it is doubtful if a sufficient volume needed for continuous hydraulicing on a large scale throughout the season could be obtained in this way. The valleys are all steep and comparatively narrow in their upper reaches, and high expensive dams would be required to impound any considerable quantity of water.

Pumping plants.

The establishment of a large pumping plant is only possible if water power be used, as the price of fuel for generating steam is prohibitive. The Klondike river could be used for this purpose. This stream has a fall of about fifteen feet to the mile, and a head of forty feet could easily be obtained in a distance of five miles. The flow, at ordinary summer level, averages about 80,000 miners' inches. Sufficient power could be obtained, by using the whole stream, to elevate about 2,000 miners' inches to the height required, to hydraulic the benches at Bonanza forks, and the plant, if necessary, could be duplicated higher up the river.

The installation of a gravity supply system is rendered difficult by the irregular topography of the country. The Klondike district, a high ridgy region, is separated from the surrounding country, except in the south-east corner, by wide valleys. It is bounded on the south by the valley of the Indian river, on the west by the Yukon, on the north by the Klondike, and on the east by the Flat Creek plain, a depression ten to fifteen miles in width, which extends from Stewart north-westward to the Klondike, and continues on past Twelve-Mile river. The Flat Creek plain separates the Klondike hills from the Ogilvie range, (in which the streams it is proposed to tap originate) and must be crossed. It is underlaid by soft Tertiary deposits, is easily eroded, and, except at the summits, is trenched with great valleys, the bottoms of which are usually below the level at which water is required. The elevation of the plain, at the summit between the Klondike and Stewart rivers, is about 2,500 feet, and at the summit between Klondike and Twelve-Mile river, the first parallel stream at the north, is about 2,500 feet.

Irregular topography.

Schemes have been proposed for supplying the camp with water from the main Klondike or one of its upper southern tributaries, from Rock creek, one of its lower northern tributaries, and from Twelve-Mile river, the first large stream entering the Yukon, north of the Klondike.

The Klondike river, after issuing from the Ogilvie range, flows westward across the Flat Creek plain, and then skirts the Klondike hills to its junction with the Yukon at Dawson. The grade of the main valley up to Flat creek, a distance of twenty-seven miles, averages about sixteen feet to the mile, and from Flat creek to the Ogilvie range is nearly the same, but increases after entering the mountains. Assuming the elevation of Dawson, at the mouth of the Klondike, to be 1,200 feet, water to hydraulic the hill gravels at the mouth of Hunker creek and Bonanza creek requires to be furnished at an elevation of 1,800 feet, and at Bonanza forks, 2,100 feet. To obtain this elevation with the water from the Upper Klondike, or its upper southern tributaries, the intake must necessarily be situated deep in the Ogilvie range, and the supply must be carried in pipes, flumes or ditches across a long stretch of broken mountainous country, and then siphoned across a part, at least, of the Flat creek depression before the border of the Klondike hills is reached. Afterwards, it could be led along the ridge separating the Klondike from Hunker creek until a favourable point be reached for piercing this ridge with a long tunnel. To supply Bonanza creek from the same source, many additional miles of piping and fluming, or a second long tunnel, would be necesary. The total length of a supply system from the upper Klondike cannot be given, as the contours of the Ogilvie range are only imperfectly known, but would probably approximate 100 miles, and inverted siphons would be necessary for a not inconsiderable portion of the whole distance. The feasibility of this plan seems doubtful on account of the great expense involved.

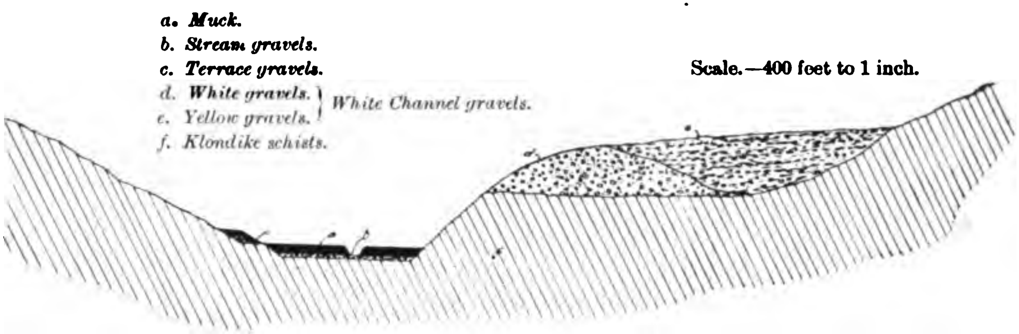
Rock creek supply.

The Rock creek scheme, although also expensive, appears to present fewer difficulties. This stream enters into the Klondike from the north, four miles above the mouth of Hunker creek. Its grade is steep, amounting to 60 or 70 feet to the mile, and the necessary elevation is attained in about twenty miles, before the stream reaches the mountains, but above its forks. About thirty miles of piping, fluming and ditching and at least one long tunnel are required to bring the water from the intake to the northern bank of the Klondike valley opposite the mouth of Bonanza creek, and an inverted siphon, a mile and a half to two miles in length, would be necessary to bring it across the valley to a distributing point. The branch of Rock creek which it is proposed to divert is small, and cannot be depended upon to give a steady supply of more than 1,000 to 1,500 miners' inches. To obtain a larger supply it would be necessary to collect, by flumes or ditches, the water from its two other main branches. Water can also be turned into Rock creek above the proposed intake, from Spotted Fawn creek, a tributary of Twelve-Mile river, and also possibly from the north fork of the Klondike. 4,000 to 5,000 inches could be obtained from Rock creek and Spotted Fawn during low water and much more in the spring and fall. An additional supply, it is claimed, can also be obtained from the north fork of the Klondike.

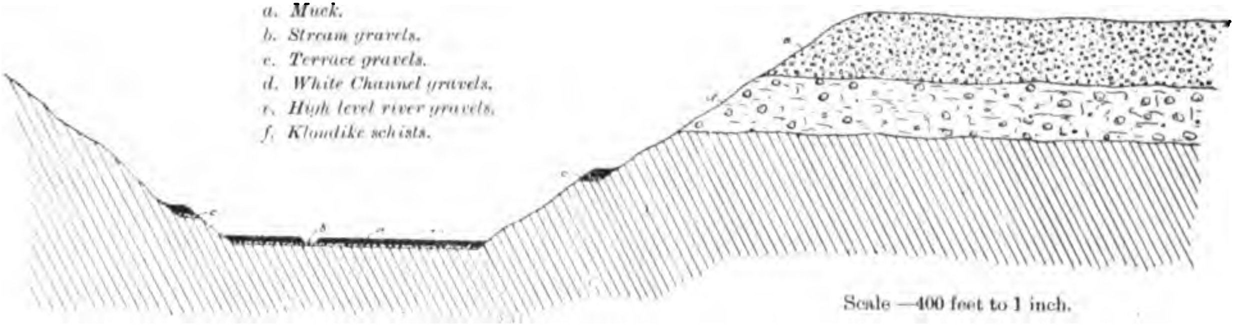
Water from Twelve-Mile river.

Twelve-Mile river, like the Klondike, heads in the Ogilvie range, and crosses the northern continuation of the Flat creek depression on its way to the Yukon. Water can be obtained from the upper tributaries of this stream at a sufficient height to place it on the divide between Twelve-Mile and Klondike, from which point it would follow the same course as the Rock creek supply.

While it is possible, therefore, to obtain water for hydraulicing the Klondike gravels, both by pumping it up from the Klondike river and by gravity from streams flowing from the Ogilvie range, the installation of a large supply system flowing from 3,000 to 5,000 inches must necessarily be a costly undertaking and if, in addition to the high initial expense, the shortness of the working season be taken into consideration, it follows that cheap water, as it is understood in more southerly regions, can hardly be expected in the Klondike.



GENERALIZED SECTION ACROSS BONANZA VALLEY BELOW ELDORADO FORKS.


a. Muck.
b. Stream gravels.
c. Terrace gravels.
d. White Channel gravels.
e. High level river gravels.
f. Klondike schists.
a
b
c
Scale —400 feet to 1 inch.

GENERALIZED SECTION ACROSS THE LOWER PART OF BONANZA VALLEY.

The thickness of the gravels and overlying muck varies along different portions of the creek. Between the two Discovery claims, the most productive part of the creek, the gravels range in thickness from two to seven feet, and the overlying muck and associated sediments from five to fifteen feet. Farther down near the mouth of Laura creek the thickness of muck and gravel increases to about forty feet. Between Laura and Sulphur creeks the depth to bedrock is usually between thirty-five and forty feet. Below Sulphur creek, the depth decreases again to about twenty-seven feet.

Origin of white gravels.

The yellow creek gravels, representing the present wash of Dominion creek, are underlaid between Burnham and Sulphur creeks and for some distance farther down by a white compact siliceous deposit, similar in every way to the high level white channel gravels of Bonanza and other Klondike creeks, and probably belonging to the same period. At first glance it appears strange to find these gravels on some creeks resting on high benches and in others underlying the present valley flats. The explanation is however simple. The elevated position of these gravels on Bonanza and Hunker creek is due, as stated before, to a recent general elevation of the country, which gave the streams increased grades and enabled them to cut deep, steep-sided secondary valleys in the floors of their old valleys. Both Bonanza and Hunker creeks empty directly into the master valleys of the district and were affected immediately by the deepening of these. Dominion creek, on the other hand, empties into Indian river many miles above the junction of the latter with the Yukon, Indian river is itself a comparatively small stream, and any increased cutting power which it acquired in common with the other streams, after the elevation of the country, has been expended in the lower portion of the valley and has not, so far, materially affected the upper portion. A secondary valley, in places narrowed to a canyon, is traceable from the mouth of Indian river up stream to a point above Quartz creek, where it merges with the older valley. The wide flats which bottom the valley of the main stream, and of the large tributaries like Dominion creek, above this point, correspond therefore in a general way to the old valleys of Bonanza and Hunker creeks, now represented by high benches, and not to the present valley-bottoms.

The white gravels on Dominion creek are comparatively thin, seldom exceeding fifteen feet in thickness, and in the lower portions of the valley, they occur, in places, as long, buried ridges running parallel to the general direction of the valley. The intervening spaces are filled with the loose, yellow wash of the present stream.

The low terraces bordering Dominion creek, above Burnham creek, indicate a slight deepening of the upper portion of the valley. The gravels on these terraces are similar to the creek gravels, except at a couple of points where they consist of angular fragments of bedrock massed confusedly together.

Gold production.

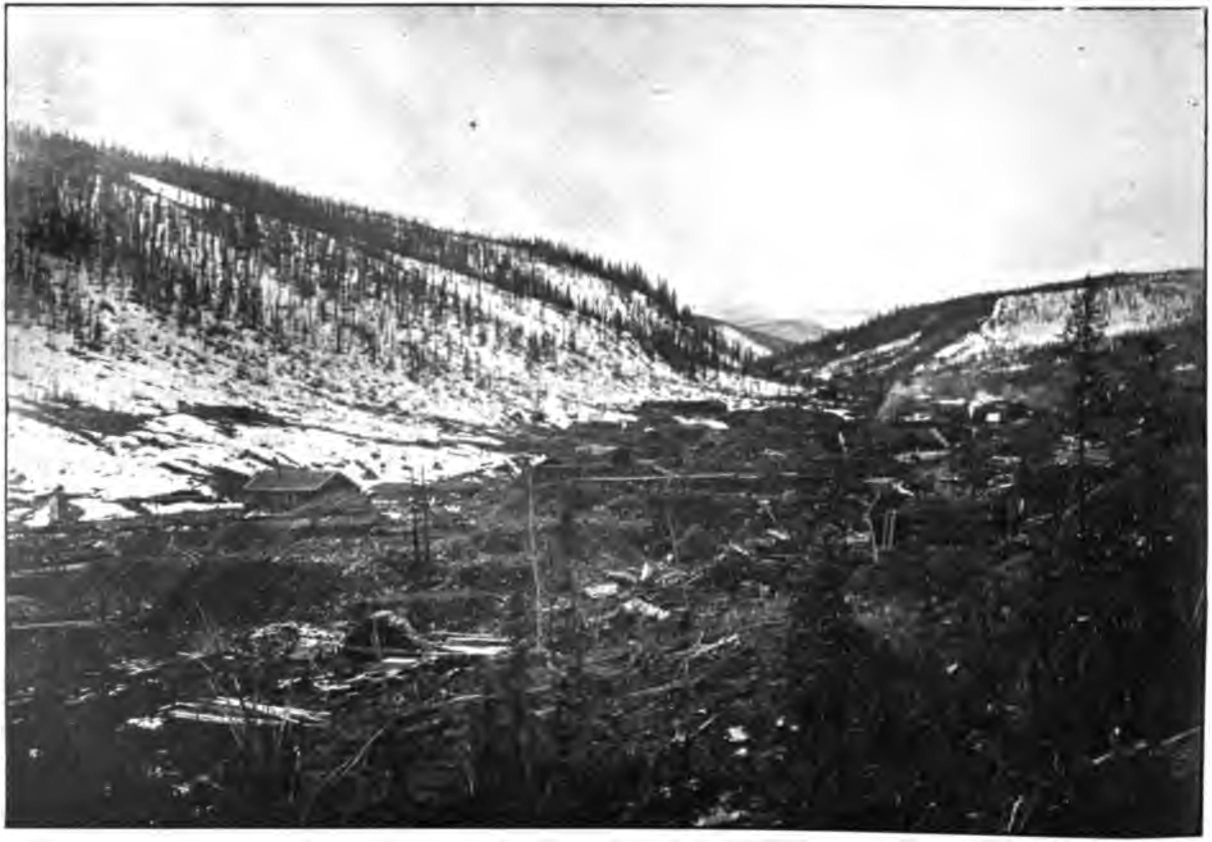
Gold has been found along the greater part of the whole length of the Dominion creek. The pay-streak begins about claim No. 22 above upper Discovery in the narrow gulch part of the valley, and has been followed, with some blank stretches, down almost to the mouth of the creek. The most productive part extends from Lombard creek down to lower Discovery and a couple of miles beyond. A yield of nearly half a million dollars worth of gold is reported from some of the richer claims in this portion. The schist bedrock on Dominion creek is softer and less open than on Bonanza creek, and the gold does not sink in it so readily. On this account an extraordinarily rich layer of gravel, a few inches in thickness, is often found immediately overlying bedrock.

Creek claims have been worked at a profit below Lower Discovery, although the pay streak is often interrupted by barren stretches, down nearly to Jansen creek, and bench claims for a couple of miles farther. No pay has been found below this, until the mouth of Gold-run creek is reached. A second rich stretch commences here and continues down to a point below Sulphur creek. Wide flats border this portion of the valley and persistent prospecting was required to discover the pay streak. The gold occurs mostly in the underlying white gravels. The claims are not rich in the Eldorado meaning of the term, but carry sufficient values in most cases to enable them to be profitably worked. The pay-streak is reported to be 1,000 feet or more in width in places.

The terrace gravels on the left limit of Upper Dominion creek proved very rich, and some of the claims in the vicinity of Lower Discovery and up the valley to near Upper Discovery, have yielded large returns for the amount of work done. Bench claims are being worked at the present time on the left limit at intervals down to Creek Claim No. 149 below Lower Discovery.

Character of gold.

The gold on Dominion creek presents the usual variety. Above Lombard creek, it occurs in rough rounded grains and small nuggets. Farther down, a mixture of heavy grains, some well-worn and others quite rough, with a more flaky variety, and an occasional large, well-worn nugget is found. Below Lower Discovery the gold becomes finer and more flaky and nuggets are only occasionally found. The gold on Lower Dominion below the mouth of Gold-run is coarser than on portions of



BIRDSEYE VIEW OF LAST CHANCE CREEK.

[p. 50.]

Upper Dominion and was probably largely derived from Gold-run creek.

The bench or terrace gold often occurs in fairly large flat grains, more uniform in size, smoother, and more worn than the creek gold.

The assay value of Dominion creek gold increases slightly but steadily, descending the valley. At Upper Discovery the average value is about $16.75 per ounce, at Lower Discovery $17.04, and at claim No. 133 below Lower Discovery $17.26. The gold from the claims below Gold-run is still higher in grade, averaging about $17.50 per ounce.

Dominion creek tributaries.

Gold has been found on very few of the numerous tributaries of Dominion creek. The streams entering it from the left are all barren, so far as known, and only three producers, Cariboo, Sulphur, and Gold-run creeks have been found on the right limit, and of these only the last two are important.

The creek gravels of Cariboo creek have yielded little or no gold, but some producing claims are being worked on a wide low bench situated on the left limit, about a mile above its mouth. This bench supports a bed of gravel ten to twelve feet in thickness, which has, in spots, proved moderately rich. The gold is coarse and rough.

GOLD-RUN CREEK.

Character of Gold-run creek.

Gold-run creek enters Dominion creek from the right, five miles above its mouth. It has a length of about eight miles and a course nearly parallel with Dominion creek above its southerly bed. It is a small stream, from six to eight feet wide at its mouth, but, except in very dry seasons, gives sufficient water for sluicing purposes.

The valley of Goldrun is a flat-bottomed depression more than a quarter-of a mile wide near its mouth. The bordering ridges are uneven, and have a height of from 1,200 to 1,500 feet above the valley-bottom, Terraces occur on the left limit, near its junction with Dominion creek. and on the right limit, about three miles above its mouth, but no continuous system exists. The country rocks consist, in the few exposures seen, of the sericite and chlorite schists of the Klondike series.

Gold-run gravels.

The gravels on Gold-run, about claim No. 13 above its mouth, are similar to those on the creeks already described. They are rather more quartzose than usual and are also irregular in thickness, the muck occasionally sinking down almost to bedrock. The thickness of gravel and muck varies from twenty to over thirty feet. Below claim No. 13, the bedrock sinks suddenly, and the overlying gravels and muck increase from twenty-five to over fifty feet in thickness. The depression is filled with white siliceous gravels similar to those on Dominion creek. They continue down to the mouth of the valley and out into and down Dominion valley. The cause of the sudden sinking of the bedrock floor of Gold-run valley is not fully understood. It is possible that the line of shafts following the pay streak down the valley may pass at this point over the edge of a buried terrace, and that a more graded channel exists in other parts of the wide valley, but this could not be proved.

Productive portion.

The productive part of Gold-run creek, like that of Eldorado creek, occurs near its mouth. The main pay-streak commences just above the mouth of No. 43 pup, and has a length of about three and a half miles. A few claims have been worked above No. 43 pup but the yield has been small. Below the mouth of this gulch, an almost continuous stretch of pay gravels has been worked down to, and out into, Dominion valley. Near the mouth, the pay occurs in the buried white gravels and, farther up, in the yellow creek gravels. The claims along the lower part of Gold-run creek, while not equal to those on Eldorado creek, proved exceedingly rich. A number of the best claims will probably yield considerably over a quarter of a million dollars worth of gold. The gold is generally rather coarse and angular, although a few smooth grains are occasionally intermixed. Nuggets are not plentiful and no very large ones have been found. The grade of the gold is high, the assay value averaging $17.65 per ounce.

SULPHUR CREEK.

Character of Sulphur creek.

Sulphur creek heads in the Dome, and empties into Dominion creek, two and a half miles above Australia creek. It has a length of seventeen miles, measured along the valley. At its mouth, it is a stream of about twelve feet wide, with an average depth of about six inches, on the bars. In the productive part of the creek the water supply is much smaller, but, except near the head, one or more sluice heads are usually available. The principal tributaries are Green, Friday, Meadow and Brimstone gulches on the left, and Quinn and Black Diamond gulches on the right.

Valley of Sulphur creek.

The valley of Sulphur creek is sunk from 1,000 to 1,500 feet below the crests of the bordering ridges. The slopes are easy and very uniform, and are somewhat steeper on the right limit than on the left. In the upper part, the valley is narrow and gulch-shaped, with a steep grade, but it gradually widens towards the mouth, and the inclination lessens. For some distance above the mouth, the grade scarcely exceeds twenty feet to the mile, measured by the aneroid. The increase in width is fairly uniform, but slight expansions and contractions occur at intervals all the way down. At the mouth of Green gulch, about five miles from the head of the valley, its bottom is 300 feet wide, and is cut by a narrow muck gorge thirty feet deep, in which the stream, here only about three feet in width, is confined. Seven miles farther down, the valley flat has a width of 750 feet, and near the mouth this increases to nearly a third of a mile. A general cross-section of the valley shows a flat of varying width bordering the stream, from the edges of which the surface rises gently to the bases of the main slopes of the valley; then, a sharp ascent of from 700 to 100 feet, followed by easier slopes to the crests of the bordering ridges. A marked peculiarity of Sulphur valley is the absence all along its course of well-defined terraces. Sulphur creek is singular in this respect, as, with the exception of Gold-run creek, where they are only feebly developed, gold bearing terraces are prominent along all the productive creeks of the district.

A second peculiarity of the valley is the continuous rise, referred to above, between the edge of the flat bordering the creek, and the base of the hills, amounting in some parts to fifty feet or more. Bench claims have been staked along this rise, but, where shafts have been sunk through it, bedrock has been found at about the same level as near the creek, and the rising surface has been shown to be due to a great accumulation of muck. It is possible, however, that, in places, terraces may be buried below the muck so completely that no sign of them appears on the surface.

Bedrock.—In the upper part of Sulphur creek and down to about claim No. 50, below Discovery, the rocks consist principally of the greenish and light greenish schists of the Klondike series, similar to those found on Upper Bonanza. The schists are cut by numerous quartz veins and by occasional bosses and dikes of quartz-porphyry. In the lower part of the valley, the schists become coarser, more granular, and appear to change gradually to a granite gneiss. Exposures are scarce along the valley, and the character of the rocks can only be ascertained from specimens obtained from shafts sunk to bedrock. Geology.

Gravels.—The gravels on Sulphur creek are similar to those on Gold-run creek. The yellow creek gravels are underlaid, descending the valley, on claim No. 55 below, by white gravels, and these continue down to its mouth. The gravels are overlaid by an unusually heavy bed of muck. On claim No. 36 above, the muck has a thickness of fifty feet, and on most of the claims the depth to bedrock is between thirty and forty feet.

Productive portion.

Gold contents of gravels.—Pay gravels occur pretty continuously along Sulphur creek, from a point a short distance above the mouth of Green gulch down to claim No. 35 below, a distance of about seven miles. The claims along this stretch are seldom exceptionally rich, and a few are barren or nearly so, but most of them yield fair returns. Gold in paying quantities is found above Green gulch for a distance of three miles, but the pay-streak is interrupted by barren intervals. Some pay has been found in spots in the lower part of the creek. The white gravels are less productive on Sulphur creek than on Gold-run and Dominion creeks.

Sulphur creek gold is lower grade than Gold-run gold, averaging about $16.60 per ounce. It follows the general rule in occurring in large angular pieces in the upper gulch part of the creek, and in small, flaky rough grains farther down. With the exception of Green gulch, on which some gold has been found, none of the tributaries of Sulphur creek have been found productive.

QUARTZ CREEK.

Character of Quartz creek.

Quartz creek heads in the Dome ridge, where so many of the Klondike streams originate, and flows southward to Indian river, which it joins seventeen miles below the mouth of Dominion creek. It is a short stream, about nine miles in length, but forks repeatedly along its its course, and, with its numerous branches, has curved out the widest and most conspicuous basin in the district. The principal tributaries are Calder, Little Blanche, and Canyon creeks on the right, and Toronto and Mack's fork on the left.

The valleys of the main stream and of the larger tributaries are bottomed with the usual wide flats. They have been deepened, resembling the Klondike rather than the Upper Indian river streams in this respect, and portions of the old valley-bottom occur as wide benches along the right limit. The benches are everywhere low, and, in places, the ground covering has been removed. Quartz creek was the first creek in the district on which gold was discovered, but the production from the creek claims, up to the present time, has been comparatively insignificant. The leanness of the creek gravels is somewhat remarkable, as this stream cuts the Klondike schicts, (the gold-bearing rocks of the district,) and with its tributaries has carried away and concentrated the metallic contents of an enormous amount of material.

A few creek claims are being worked at intervals from the mouth of the creek up to claim No. 18 above Redford's Discovery. At Redford's Discovery, the creek has been displaced over a hundred feet by the slow advance of a heavy bed of muck on the left bank. The pay gravels are overlaid by about seventy-five feet of muck, and are reached by inclines from the present creek channel. A number of the claims above and below Redford's Discovery have been worked at a profit.

Bench gravels.

The bench gravels on Quartz creek are more important than the creek gravels. A gravel-covered terrace follows the right limit from Canyon creek down to Calder creek and also extends for a short distance above and below these creeks. Below Canyon creek, the terrace is a third of a mile wide and 110 feet high, but decreases both in height and width, descending the valley. It is built principally of gravel, the underlying bedrock having an elevation of only a few feet above the present valley-bottom. The shafts to bedrock on the various claims vary in depth from 100 feet to sixty feet or less. Near Calder creek the pay-streak approaches the edge of the valley, and the deposit is worked by open cuts.

The Quartz creek bench gravels consist of compact grayish gravels below, and looser yellowish gravels above. They are darker in colour and less siliceous than the white channel gravels of Bonanza creek, but are very similar in other respects, and are referred to the same period. They are moderately rich, the pay occurring as usual in the lower few feet of the deposit, and a large number of claims are being worked.

The tributaries of Quartz creek are not important, although a few claims have been worked with success on Little Blanche and Canyon creeks.

EUREKA CREEK.

Character of Eureka creek.

Eureka creek flows into the Indian river from the south, five miles below Dominion creek. It is a small stream, about eight feet in width, where it enters Indian River valley, and about ten miles long. It divides, three miles above its mouth, into two nearly equal branches, both of which head in a range of high hills that border this part of Indian River valley on the south.

The valley of Eureka conforms to the general type of the district. In the lower part, the muck-covered flats bordering the stream are from 300 to 900 feet wide. A well-defined bench, fifty feet in height, occurs on the left limit opposite the forks, and continues up the creek for a couple of miles. At No. 4 above Discovery, the bench is ninety feet in height.

Geology.

Country rocks.—The rocks on Eureka creek differ from those on the other gold bearing creeks in the district. The Klondike series occur near its mouth but is soon replaced by the slates quartzites and dark and green schists of the Nasina series, and these continue to the head of the stream. The discovery of gold in streams cutting these rocks is important, as they have a wide distribution throughout the territory.

Gravels.—The Eureka stream-gravels consist, mainly, of imperfectly rounded pebbles of dark and green schists. Quartz pebbles and boulders, sometimes of large size, are also present, and granite occurs occasionally. In the upper part of the valley, the gravels, as usual, become coarse and angular. The creek gravels are from four to eight feet in thickness, and are overlain by from ten to twenty feet of muck. The terrace gravels consist of the same materials as the stream gravels, but are rounder and more worn. Quartz pebbles are also rather more abundant. Eureka creek is not a rich creek, but a number of claims have been worked at a profit, both in the main valley and on both forks. On the left fork, the pay-streak follows what is known as No. 18 pup, and up to the mouth of No. 13 pup continues up the latter for a few claims. The gold from the right fork is very coarse, and nuggets worth from twenty to fifty dollars are reported. The grade of the gold is low, averaging about $14.59 per ounce. The Eureka creek terrace gravels contain some gold, and a couple of claims are being worked on them.

Productive portion.

MINING METHODS IN THE KLONDIKE.

Creek claims are worked, with few exceptions, either by sinking and drifting, or by open-cut work. A description of these two methods is given by the writer in the Summary Report for 1900 and the following account is partly a repetition of that.

Drifting method.

The greater part of the claims are worked by the first method. A shaft is sunk to bedrock, and the pay gravels around the foot of the shaft are thawed out and hoisted to the surface. If the work is done in the winter, the material is piled up in great dumps and sluiced in the early spring; if in the summer time, the two operations are carried on simultaneously. In the better-worked claims, a system of drifts is extended from the shaft or shafts to the edge of the claim, or of the pay, as the case may be. The drifts are connected by cross-cuts, and the farther blocks are worked first.

The gravels are everywhere frozen, and require to be thawed before they can be extracted. This was done in early days by wood fires, or by heating the water at the foot of the shafts with hot stones, but now, except in remote districts, is done altogether with steam thawers or pumps.

Thawing by steam.

Thawing by steam is a simple operation. The steam is usually obtained from the boiler that furnishes power for hoisting and other mining operations. It is passed through rubber hose, to the ends of which pointed steel tubes, four or five feet in length, are attached. The latter are driven into the frozen gravel and steam is forced through them for a period of from six to twelve hours. They are then withdrawn and the thawed material is removed. The points require steam equal to about one horse power each, and thaw from one to three cubic yards of gravels at a shift. Any number can be used.

Thawing by water.

In thawing with water, a small Worthington pump with a three inch discharge, and three quarters of an inch or inch nozzel is usually employed. Only a small amount of water is required, as the stream played against the gravel face is collected in a sump and used again repeatedly. The relative merit of steam and water thawing is still an open question among the miners. The size of the excavation can be more easily regulated with water, as the steam, especially in the summer time, heats the air in the chamber, and portions of the waste in the roofs thaws out and falls. Steam is used on the majority of the claims.

Timbering.

Timbering is seldom required, as the bed of frozen muck which overlies the gravels forms an extremely tenaceous roof, and chambers of astonishing size can be excavated beneath it, in the winter time, without danger. In one case, on Dominion Creek, a muck roof, unsupported by pillars, covered a vault said to measure 140 feet by 230 feet, and remained unbroken until midsummer. Examples of muck roofs spanning vaults over 100 feet in width are common.

Open cut method.

In working claims by the second method, that of open-cuts, the first object is to get rid of the muck covering. This is easily done in early spring by taking advantage of the spring floods and leading the water by several channels across the claim. The muck thaws easily and the streams soon cut down to the gravel, and then gradually widen their channels until they meet. In some cases, the process is hastened by blasting out the walls of the muck channel with slow explosives.

When the muck covering is removed, the gravels usually thaw to bedrock in a single season. The upper portion, if barren, is removed and piled up where most convenient, and the underlying pay gravels are shovelled up or hoisted in buckets, and sluiced in the ordinary way. The open-cut method of mining leads to a more complete recovery of the gold, but is too expensive to be used where the barren overburden of muck and gravel exceeds ten to fifteen feet in thickness.

While the general system of mining creek claims has changed very little since the early days of the camp, there has been a great improvement in the plant employed. Wood fires, for thawing, as stated before, are now altogether superseded by steam thawers and pumps. The hand windlass has been replaced by steam hoists working with self-dumping buckets, and steam scrapers are used, instead of the shovel and wheel-barrow of early days, to remove the waste in open-cuts. On many of the claims the water for sluicing purposes, instead of being flumed from a point up the creek distant enough to give the required grade, is now pumped up, and the sluice boxes are placed high enough to carry the tailings where required. The employment of steam power and machinery, in place of hand labour, has reduced the ordinary expenses of mining by nearly one-half, and has given value to long stretches of gravel on the various creeks formerly too low grade to work.

The equipment required to work a creek placer claim at the present time by the drifting method, where the water for sluicing is pumped up, consists of a 35 to 50 H. P. boiler for furnishing power, a hoist and self-dumping bucket worked by an 8 to 10 H.P. engine, a centrifugal pump with a 6 inch. discharge for elevating water for sluicing, (driven by a 15 H.P. engine,) and a small Worthington pump with three inch discharge, an inch nozzel for thawing or a set of points when the thawing is done by steam. The installation of the plant on one of the distant creeks usually costs from $5,000 to $7,000. The operating expenses on an ordinary claim, with one shift and night thawing, amount to about $100.00 per day, and from 50 to 60 cubic yards of material are mined and sluiced daily.

Dredging.

On a few claims in the district, the mining methods are different from those described above. A dredge, originally intended for work on the bars of the Lewis river, has been operating on Bonanza creek for the last three seasons. The work done has shown that, where the gravels are completely thawed, they can be worked very cheaply by dredging, but where frost is encountered, thawing, as in the other methods, must be resorted to. In dredging, also, the bedrock is not seen, and there is always some uncertainty in regard to the completeness of the recovery of the gold. Where the bedrock is hard and blocky, the gold often sinks down along the jointage and bedding plane to a depth of from three to five feet, and part of it must almost necessarily be left behind. In soft bedrock, it is probable that the recovery of the gold is nearly complete, as it does not sink so deep, and the material containing it is easily removed.

Steam shovels

Steam shovels are being used on several claims in the district, and where the conditions are suitable they handle the gravels and certain kinds of beds cheaply and effectively. The overlying muck requires to be sluiced off in the usual way, and the gravels must be thawed out.

Another attempt, worth mentioning, at cheap mining on the creeks, introduces the hydraulicing principle, but is still only in the experimental stage. On the Gold-run creek, a couple of claims have been equipped with long China pumps and bucket elevators. The pump and gravel elevator, each about seventy feet in height, rest in a sump excavated twelve to fourteen feet deep in bedrock. The gravels are washed into the sump by a stream of water under a small pressure, and are carried up by the bucket elevator and dumped into the sluice boxes. The China pump elevates the water used in hydraulicing, and it serves again to wash the gravels. If this method prove successful, a number of other claims in Gold-run creek will be equipped in a similar manner.

High level gravels.

The pay-streak in the elevated white channel gravel is worked from drifts along bedrock starting at the rim, or, when the deposit is wide, from the foot of the shafts, often over a hundred feet in depth, sunk to bedrock. A small amount of open-cut work is usually done along the rim.

Scarcity of water.

The scarcity and, in places, almost complete absence of water has greatly hampered mining operations on the benches. In early days the pay gravels were largely washed in rockers or trammed down to the creeks, and sluiced there. Ditches have now been constructed to the heads of some of the creeks and gulches tributary to the main valleys. The supply from these is, however, usually small, and only available for a portion of the season.

Numerous attempts have been made to pump water up from the creeks to sluice the hill gravels, but in most cases, with indifferent success. The Electric Power Co. of Dawson is now operating several small pumping stations along the Bonanza creek, but the price charged, $7 to $8, per sluice-head per hour, is prohibitive, except on the richer claims.

Hydraulicing.

Water obtained by pumping.

A few hydraulic plants, some using water pumped up from the creeks, and others gravity water, have been installed at various points to work the hill gravels. The pumping plants have not proved successful in the past, but experiments in this direction are still being tried. The installation of the largest pumping plant in the district was commenced and nearly completed during the past season by the Pacific Coast Mining Co. The plant is situated at the mouth of Adams creek, and is intended to work a group of claims owned by the Company on Chechaco hill, originally one of the richest on Bonanza creek, but now largely drifted out. Two pumping engines will be employed when the plant is in full running order, the main one having a capacity of 3,000 gallons per minute against a head of 350 feet, and the auxiliary one of 1,500 gallons per minute. Power is furnished by two Cahall water-tube boilers, giving, together, 528 h.p. It is intended to force the water through two twelve inch discharge pipes up to a

supply of 200 inches is available for a few weeks in the spring and fall, and is delivered under a head of about 200 feet. In Mr. Coffey's report to his Company, in 1902, it is stated that in a run of twenty-two days 29,000 cubic yards were sluiced, and that the actual hydraulicing cost was under fifteen cents per yard. The total operating expenses, including cost of plant and cleaning bedrock, were thirty-five cents to the cubic yard, or $1.96 per square yard of bedrock. In the same report it is stated that the actual average cost of mining and sluicing by the ordinary drifting method amounted to $5.85 per square yard of surface. No allowance is apparently made in the statement for the original cost of the water-right and flume. This comparison in cost between the two methods is, however, scarcely fair to the latter, as the hydraulicing operations

GEOLOGICAL SURVEY OF CANADA
ROBERT BELL, D.Sc. (CANTAB.), M.D., LL.D., F.R.S., I.S.O.

REPORT

ON AN

EXPLORATION

OF

EKWAN RIVER, SUTTON MILL LAKES

AND

PART OF THE WEST COAST OF JAMES BAY

BY

D. B. DOWLING, B.Ap.Sc.

APPENDIX I.—*Preliminary list of fossils by Dr. J. F. Whiteaves.*
" II.—*List of plants by Prof. John Macoun.*

OTTAWA
PRINTED BY S. E. DAWSON, PRINTER TO THE KING'S MOST
EXCELLENT MAJESTY
1904

14—F

No. 815.

To Robert Bell, M.D., L.L.D., F.R.S., ETC.

Director Geological Survey of Canada.

SIR,—I have the honour to submit the accompanying report for 1901 on the country traversed by the Ekwan river and of a route thence northward through Sutton Mill lakes and down Trout river to Hudson bay, together with a short description of the west coast of James bay. The map which accompanies the report is compiled from our own survey of Ekwan river to Washagami river and track-surveys of the route northward to Hudson bay with log-survey of Sutton Mill lakes and part of the west shore of James bay. In this work I was ably assisted by Mr. W. H. Boyd who performed most of the instrumental surveying. A list of the fossils collected, by Dr. Whiteaves and another of the plants by Prof. Macoun, are appended.

I have the honour to be, Sir,
Your obedient servant,

D. B. DOWLING.

Geological Survey Office,
Ottawa.

REPORT

ON A

SURVEY OF THE EKWAN RIVER

AND OF THE

ROUTE THROUGH SUTTON MILL LAKES NORTHWARD

By D. B. Dowling.

General features. The country included in the angle between Hudson bay and the west shore of James bay, is drained by several large streams running mainly to the north-east. Those entering James bay incline to the east after running north-east for a large part of their courses. The whole surface slopes gradually to the north and east, and the greater part of it is covered by a heavy deposit of clay and sand. On the north slope, or that lying south of Hudson bay, proper, the deposit is thicker than on the slope to James bay. On the Fawn river, a branch of the Severn, Mr. Low reports *high cut banks of clay near the junction with the Severn, which are as much as two hundred feet above the stream.

In the valley of Sutton Mill lakes there is a heavy cut, such as that mentioned by Mr. Low on the Fawn. The lake is very deep for its width, and the banks, where they are of clay, are 100 feet above the water, while several soundings in the lake gave a depth of over 200 feet. The submersion of much of this area has been proven by the presence of salt water shells in the surface deposits.

On the Attawapiskat river, Dr. Bell does not mention such an accumulation of drift, while our own observations on the Ekwan show that the general depth of the drift covering is about 100 feet.

Recent uplift. The recent uplift of the land, as observed by Dr. Bell in several places to the south of this, is as much as 500 feet. At the highest point reached by the marine terraces in the vicinity of Sutton Mill lakes the elevation was determined by simultaneous readings of aneroids at the lake and on the shore of Hudson bay at the mouth of Trout river. The western limit of these clays on the Albany river is below Martens falls and on the Attawapiskat near the mouth of the Black Fence river. On the Ekwan, the edge of the deposit was not reached, and on the Severn, the marine clays were found on the Fawn branch near the first outcrop of Laurentian rock. At the period of greatest submergence the sea covered a large part of the area under discussion, but it is quite possible that part of the elevated ridge, consisting mostly of Cambrian rocks, in the latitude of Sutton Mill lakes was either out of water or formed shallow reefs or a chain of islands.

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* Annual Report Geol. Surv. Can., Vol. II (N.S.) 1886, p. 18 F.

Course of streams probably changed

On the removal of the great mass of the glacier and the consequent inauguration of the retreat of the sea and elevation of the land, the former lines of drainage were more or less blocked by the deposit left by the glacier and a new system of drainage was consequently formed. That some of these streams changed their courses as the upward tilting of the land took place, is very probable. In the case of the Ekwan, the upward tilting to the north caused the deflection of the stream from the valley through which it ran on its way to the sea to the north of Sutton Mill lakes. The deflected part of the river is now the section below the Little Ekwan and is noticeable as being much newer than the upper part.

Surface covered by thin forest.

The general surface is very even on that part covered by the marine deposit, and is a gently sloping plain covered for the most part by a thin forest of black spruce and tamarack, In the river valleys, especially near the streams, other trees occur, notably the poplars (*Populus tremuloides* and *P. balsamifera*) and birch. In the case of the latter tree, few large ones occur north of the Albany river, and the Hudson's Bay Co. have established a canoe-building industry at Albany post to supply the Indians coming from farther north. On the Ekwan, a solitary birch was seen, and that was only a small sapling on one of the islands. Five individuals of the Banksian pine were seen in one group on the north bank fifty miles up the river, so that the northern limit of both birch and Banksian pine may be said to be south of this stream. Poplar follows the valleys of the streams nearly as far north as the spruce. The country behind Cape Henrietta Maria is treeless, as is also a strip of the coast both to the south and the west of the cape.

Survey of Ekwan river.

A micrometer survey of the Ekwan river was made to the mouth of the Washagami branch, a distance of one hundred and fifty miles.

The general valley is a narrow cut through clay, with cut banks on either side for most of the distance to the first branch.

The country on either side is covered by a mossy swamp with a sparce growth of black spruce and tamarack. The course of the river, from the mouth of the Washagami, is east-south-east, but above this it evidently takes another direction, changing its upward course toward the south and, as its head-waters lie between the heads of the Attawapiskat and Winisk rivers, it probably flows to the north-east for some distance before turning to the east. The upper part is an older channel and its course, as before mentioned, was probably through the Sutton Mill lakes valley to the shore of the bay, which was at that time not so far from the lake as at the present time. In the latter part of its course, it is now cutting down a new valley through marine clays which cover the underlying rocks to a depth varying from twenty to fifty feet. From the lowest rock exposure to the sea, the current is swift and it is constantly moving a large quantity of gravel and finer material towards its mouth, and into the bay into which it empties. Limestone in apparently horizontal beds is exposed at intervals in that section which lies between forty and one hundred miles from the sea. From the fossils collected it would appear that they are probably of Silurian age.

Forming new valley.

Above the Little Ekwan, the river issues from a wide valley which is cut through a higher plateau, but this valley gradually narrows before the Washagami is reached, and cut banks of clay, higher but somewhat similar to those in the river below, occur at many of the bends. These clays contain marine shells such as *Saxicava rugosa*, *Macoma calcarea*, *Mya truncata* and *Cardium ciliatum*. These were also found about 390 feet above tide at the highest point at which the clays were seen. In the bed of the river the living fresh water species noticed were :

Marine clays.

Anodonta Kennicotti Lea, *A. marginata*, Say, and *Lampsilis luteolus (Lamarck)* var., as identified by Dr. Whiteaves.

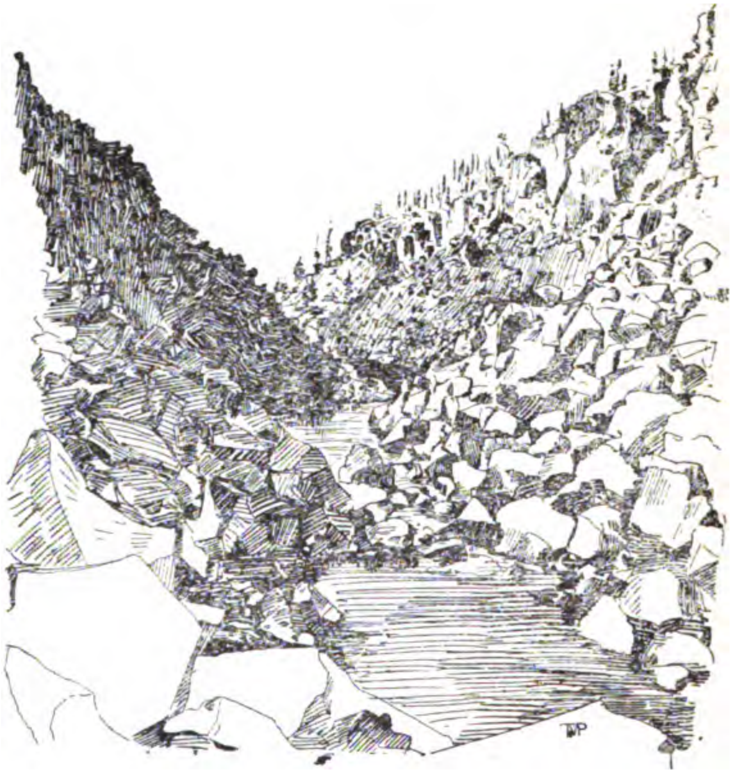
The Washagami river is but a small stream, divided a few miles from the Ekwan into two branches. The northern branch comes from a long lake-valley running north and south, or parallel to that of Sutton Mill lakes, and this may also have been one of the outlets for a stream such as the upper part of the Ekwan. The lower part of this valley or the portion near the Ekwan, is now being cut into by the stream and a short new valley eroded.

Washagami river.

The fall in the Ekwan from the mouth of the Washagami, as given by our barometric readings, is over 300 feet. North of this, to beyond

Fall in stream

Sutton Mill lakes, extends a plateau which is at an elevation of 400 feet above tide. Through this, in latitude 54° 20′, rounded or oval masses of trap protude to a height of from fifty to one hundred feet. Through the plateau, on a line where there is also a break in the trap rocks, a deep narrow valley has been eroded in a north and south direction, which is now occupied by the waters of Sutton Mill lakes. At the lake the surface of the clay plain is 390 feet and the surface of the water of the lake is 290 feet above tide. Soundings show that the bottom of the southern part of the lakes is 310 feet below the plain and that of the northern part 250 feet below this datum or only forty feet above tide.



Drawn by P. M. Papineau.

CLIFFS OF TRAP AND CHARACTERISTIC TALUS AT GORGE, NARROWS OF SUTTON MILL LAKES.

Silurian limestone on Trout river.

Silurian limestone is found on Trout river, which drains Sutton Mill lakes, and is also found in the bed of the lake just north of the trap rocks. The rocks at the narrows of the lake are cliffs of trap one hundred and fifty feet high, capping beds of probably Animikie age*. These are dark slates impregnated with iron ore and interbanded with beds of jaspilyte. Some of the beds contain a high percentage of magnetite. On the east shore a section of about ninety feet of these jasper and iron-bearing slates is exposed above the lake, but on the west side they have been brought down to below the water level by a series of north and south faults, and the exposures there are of the trap alone. These rocks form an east-and-west ridge reaching to the upper lakes on the Washagami, and eastward to a large lake on a branch of the Trout river which, as before stated, drains Sutton Mill lakes and runs to the north. The slates and jaspilyte or jasper-sandstone beds form a long anticline, whose axis runs east-and-west, and the majority of the beds exposed belong to the northern slope of the anticline. This ridge is terminated on the lake by a series of north and-south faults with downthrow to the west of unknown amount. The overflow of trap appears to have been at a later date, as there seems to be some unconformity at the base of the trap, the flow having filled all the inequalities in the underlying surface. The cliff at the west side of the narrows is of trap, one hundred and fifty feet high, with none of the jaspilytes showing beneath it. On the east side, however, ninety feet of these beds are exposed, with a varying thickness of trap above them.

Iron bearing slates.

The shore of James bay is low and shallow, and a short description as given in the summary report is here added. The delta at the mouth of the Moose river is divided into three channels which enter James bay. The northern one runs from north of Middleboro island to the north-west of Ship Sands, but it is nearly dry at low water and is also impeded by large boulders, so that it is not used except by canoes and small boats. The southern channel is also reported to be shallow. The central channel, which runs along the south edge of the Ship Sands, shoals to seven feet at low tide, and vessels pass at high water after having been lightened to draw about twelve feet.

Description of shore of James bay.

Northward from the outer bar to North point, the water is very shoal, but it deepens slightly to Nomansland. The low-tide flats are not very wide, but bars project from many of the points for long distances, as at Long Ridge and Cockispenny points. At Halfway point, limestone fragments are pushed up along the shore from rock apparently *in situ* below tide. Long Ridge point is built up mostly of gravel, with a few boulders showing on the surface. From Nomansland to the Albany river the shore is very flat, and at low tide the mud shoals extend out for several miles.

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* In my written instructions from Dr. Bell he predicted that these rocks would probably prove to be of this age and not Laurentian, as had been previously supposed. See Summary Report, Geol. Survey for 1901, p. 113.

Mouth of Albany river.

The Albany river, like the Moose, is divided at its mouth into three channels. The trading establishment and mission are situated on an island on the north side of the southern channel. North of this island is the broad opening called locally, North river. This has a long bar at its mouth, similar in position to the Ship Sands at Moose. The southern entrance to this is the larger, and it seems to be much deeper than the channel going to the settlement. The small channel north of the bar is shallow at low water and has a bar outside on which we found a depth, at high tide, of very little over one fathom. Very shoal water, in which boulders appear, extends northward beyond Nottashay point and boats are obliged to keep nearly out of sight of land to escape the shoals. Chickaney river, which enters north of the Albany, is said to be another channel from the same river.

Shoals.

Shoals were observed well out from shore to near the Kapiskau river. In the inner water between Akimiski island and the mainland there seems to be a maximum depth of about two fathoms. This shoals gradually to one fathom at a distance of three miles from either shore. The mainland is generally without a beach and between the woods and the tide-line is a wide flat covered with grass. The north-west part of Akimiski island approaches the mainland much closer than is shown on the maps, and a number of shoals are scattered from hence to the point south of the Ekwan river. The boat channel, according to our guide, runs to the west of the two islands which here lie off the shore. The position of the mouth of the Ekwan river according to several observations, is in latitude 53° 14' 0".

Description of shore north from Ekwan river.

Northward from the Ekwan, the shore, for a long distance, is flanked by high gravel bars, but at low tides a broad belt of mud extends out several miles, so that travelling along this coast with canoes is very unpleasant should the time of high water be in the middle of the day or night. Landing on the beach without a long "carry" through the mud is only possible at high tide.

The rivers that enter the bay between Niahkow point and Cape Henrietta Maria are not large and, as the former maps are mere sketches, it is difficult to locate those which are not known by a local Indian name. The first stream north of the Ekwan is a small channel said to be a branch from that river. It is marked by two gravel bars to the north about a mile from the beach. Swan river, which is perhaps Raft river of the map, enters in latitude 53° 36'. It is in a

Swan river.

slight bay or curve in the shore line. In latitude 54° the shore takes a curve to the west, forming a point and, as the tree-line curves to the north-west from here, this is probably Point Mourning, the first wooded point south of Cape Henrietta Maria. Several small streams flow into this bay. The first is called by the Indians, Nowashe river—the next Patchipawapoko—then the largest along this coast, the Opinnagan, followed by the last stream Nikitowasaki, fifteen miles north of the Opinnagan. The latitude of the mouth of Opinnagan river, by observation, is 54° 12′ 24″.

The bay to the south of Cape Henrietta Maria is shallow and muddy with wide mud flats, but near the extreme eastern end of the cape, the shore is reported to be bolder, and limestone beds are said to outcrop at high tide mark. These are probably continuations of those found on the Ekwan and Attawapiskat rivers to the south-west.

The timber along the coast gradually becomes smaller in going northward and the tree-line recedes from the shore, leaving it finally at the Opinnagan, so that the country behind the cape is more or less an open plain. The shore, where the trees are at a distance from the beach, is generally an even mud slope, covered above high tide with grass, followed by a wide belt of stunted gray willows which give an appearance like the sage bush of the plains. Behind this, a few isolated spruces of small size appear before the tree-line is reached. In sailing along this coast, it is impossible to know which way to steer so as to run parallel to the land as nothing is to be seen ahead by which to shape one's course.

Tides, Fur bearing Animals and Game.

Rise and fall of tides not regular.

The tides along this narrow shore are not regular in their amount of rise and fall, which is determined in a great measure by the direction and strength of the wind. From the Ekwan river northward, the high tide appears to be about six and a half hours after the moon's meridian passage—the flood and ebb running seven and five hours respectively, while to the south of the shallow ground between Akimiski island and the mainland, the flood comes from the south and is much earlier. High tide at Lowasky river occurs at between two and a half and three hours, and at Albany about the same. The flood tide at Lowasky river runs four hours and the ebb eight. At Albany the flood runs five hours and the ebb seven. At the outer bar at Moose river the tides are from half an hour to an hour earlier.

Fur-bearing animals and game.

Fur-bearing animals are not particularly numerous, but the Indians bring in to the Hudson's Bay Company's posts, fox, otter and beaver Caribou are occasionally secured but not in large numbers. Black skins. bears are also occasionally killed. Last season (1901) I was informed that the Indians on Akimiski island killed three white or polar bears during the early summer, and one was seen by our party along the coast north of the Ekwan.

In the interior, the game birds are all very scarce, the fall hunt for ducks and geese being confined to the shores of the bay. The rivers afford a limited supply of whitefish, and a small species of this fish is caught in the tide-water along the west shore of James bay. The nets are set or hung on stakes on the tide flats, and are covered by the tide for a few hours each day. Sutton Mill lakes are well supplied with a slender variety of gray trout and the streams running to the north into Hudson bay are, at certain seasons, well stocked with brook trout. In August the stream draining Sutton Mill lakes was full of these fish, and several fine specimens were caught on the lake above at the narrows.

Historical summary.

Early explorers of Hudson bay.

The southern coast of Hudson bay, east from Port Nelson (York Factory), was visited or explored by Captains Luke Fox and Thos. James in 1631, and again visited by James in 1632. These two navigators met off the coast near the mouth of the Winisk river on August 29-30, 1631. Each had given a name to the country to the south-west. Fox called it 'New Yorkshire' and James 'The South Principality of Wales' probably on account of the previous name 'New Wales' given by Button in 1612 to the land southwest of Port Nelson. These two navigators sailed together eastward to the entrance to James bay and there separated, Fox to go north and James southward into the bay to winter. Fox called the cape he had left 'Wolstenholmes Ultimum Vale.' James, after rounding the cape, determined its latitude (55°.05′) and called it Cape Henrietta Maria, after the queen and also after his own ship. His name for the cape has been retained and his description of the coast near it is still very true and is in a concise form * :—'From Port Nelson to this cape the land, trends (generally) east-south-east, but makes with points and bays, which in the particulars doth alter it a point, two, or three. The distance is about one hundred and thirtie leagues. The variation at the Cape, taken by

Description of coast by Capt. James.

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* Voyages of Fox and James to the North-west. Haklyut Society, p. 490.

Amplitude, is about sixteene degrees. A most shoald and perilous coast, in which there is not one Harbour to be found.'

He did not follow the shore far to the south of the cape, but made out to the Bear islands and so on to the south end of Charlton island, where he wintered. Returning in the summer (1632) he landed at the cape and set up a cross with the arms of the king and of the city of Bristol.

The eastern face of the point seems to have deeper water off it than along the north shore, as James anchored in six fathoms about a mile from the shore. He reports a long shoal point running out to the northward or north-east.

Description of coast from Seven river to Cape Henrietta Maria by Capt. Coats.

In a publication by the Haklyut Society entitled 'The Geography of Hudsons Bay' by Capt. Coats (an officer with the H. B. Co. from 1727-1751), the description of the coast from Severn river to Cape Henrietta Maria in written for the information of sailors, but in it is given some indication of the character of the land as well. The following extracts from the above work give the main part of Coats' description (*see* pp. 46-52.)

'From Severn river to Cape Henrietta Maria, in latitude 55° 10′ N., the course is E. S. E., to westward of which in 55° 30′ near Cape Lookout is some broken ground, banks and ridges a great way off, come no nearer than seventeen fatham; the land very low and fenny, appears here and there in tufts of tree.

To southward of the Cape the land runs S. S. E., very low but clean even soundings with wood in some places. The shore is flatt a good ways off.'

Point Mourning.

'....Near the same latitude (54° 38′ to 54° 28′) on the west main is a bluff of wood, called Point Mourning, from the burying of one of Captain James men there. The land to northward of this, and westward of the Cape is all a low fenny unbounded marsh, not to be seen but in fine weather, so your lead is your principal guide.'

The topography of this coast and of the western side of James bay has been but roughly sketched by these navigators and little altered by subsequent ones. The streams draining to Hudson bay, as also those flowing eastward, were mapped from sketches made by various officers of the Hudson's Bay Company. The route through Sutton lakes, by the Little Ekwan river was sketched by Mr. Thos. Bunn in 1803. Later, a route to the Winisk *via* the Washagami branch of the Ekwan was mapped from a track-survey or sketch by Mr. Geo. Taylor in 1808. This latter route is not used by the Indians of the present

Routes changed.

day as perhaps the streams to be navigated are too small. The Little Ekwan is now reported to be blocked up by driftwood and the old routes are totally changed. The route to the lake is now from the Washagami eastward over a long stretch of muskeg, and that to the Winisk in made by a portage from farther up the Ekwan, direct to a small stream, a tributary of the Winisk.

The information as to the origin of the topography which appeared on the old maps is obtained from a manuscript map compiled for the Hudson's Bay Company to show the explorations of Mr. Peter Fiddler. This is now in the office of the Geographer, Interior Department. These sketches were no doubt supplied to Arrowsmith and were since reproduced on all the maps of this district.

Survey of Attawapiskat by Dr. R. Bell.

The Attawapiskat, river at the southern boundary of this district, was surveyed in 1886 by Dr. R. Bell, who the same year completed his survey of the Albany river. The same season Mr. A. P. Low traversed the country to the west from Lake Winnipeg to the Severn river and descended the latter stream to the sea. Instead of following the main stream for the whole distance, he crossed from Severn lake to Trout lake lying to the east and descended the eastern branch or Fawn river, joining the main stream about fifty miles from the sea.

EKWAN RIVER.

Outlet of Ekwan river.

Of the many outlets at the mouth of this stream, the principal or that having the greatest depth of water, is the central one. Several small wooded islands are situated at the mouth, and to the east of these the several branches of the stream flow over boulder and gravel flats to the sea. At high tide the level of the river is only affected as far up as the first wooded island, and at low tide there is about a mile of swift current from this point to the sea. Boats entering at low tide have only about two feet of water at the steepest slope. In the spring there is probably sufficient water to float boats drawing over four feet of water.

Strong current.

There is a strong current in ascending the river for the first eighty miles, and, in this part, the whole distance is usually made by tracking the canoes. In the present condition, the sides of the valley are generally free from bushes and trees, so that there is good walking along the bank.

After passing above the islands in the mouth of the stream, it is found that the river has cut down through a terrace of clay with a small percentage of sand and pebbles. The pebbles are generally found near the surface of the terrace—here about fifteen feet above the stream. The eastern edge of this terrace slopes steeply to the sea and, as it is wooded to near high tide mark, scarcely any trace of it is seen from the sea. The tide flat which borders the coast is probably derived from the denudation of the edge of this terrace. The absence of cliffs or cut-banks along the coast would indicate a recently receded shoreline.

Timber consists of small spruce and tamarack.

The surface of the terrace was found to be covered with a thick coating of moss, and the timber on it is mostly small spruce and tamarack. Some of the trees might be from six to eight inches in diameter but the average is much less. At the edge of the bank a fringe of larger trees occasionally appears, but it does not extend far from the stream. The exposures on the banks show the terrace to be made up mostly of stratified clay and sand, near the surface, with a fine clay of soft texture beneath. Of the boulders and pebbles in the channel of the stream and along the sloping banks, fully fifty per cent are of light yellowish-gray limestone and the remainder are of Huronian and Laurentian crystallines. Occasionally, bits of red quartzite and iron-bearing shales from the rocks of the Nastapoka Group were seen. Large boulders of greenstone, having rounded inclusions of coarser texture and lighter colours, occur here as well as on most of the streams entering James bay. These are also probably derived from the amygdaloids in the upper part of the Cambrian sections found on the east side of Hudson bay.

Not far from the mouth, the river again divides into a number of channels, and the banks in this vicinity are only about ten feet high. The current increases slightly and several swift places, are caused by an accumulation of boulders in the channel. A small branch channel, running north to the bay north of Niahkow point, leaves the river from behind some of the islands of this group. The river continues with swift current and is divided in a few places by islands.

Fossils.

Thirty-three miles from the mouth, the first strong rapid occurs, and the underlying limestones outcrop ,in a ledge running across the bed of the stream. The beds are lying apparently horizontal, and are of a grayish-white dolomitic limestone holding a few badly preserved fossils, from which Dr. Whiteaves describes or identifies the following :—

Favosites Hisingeri; *Trimerella borealis*; *Reticularia septentrionalis*; *Euomphalus* sp. indet.; and *Bronteus Ekwanensis*.

Limestones outcrop at Middle rapid.

In the next ten miles, which is the distance to the portage at a series of heavy rapids, there are two stiff rapids at which the limestones outcrop. At the heaviest of these, called the Middle rapid, the fall amounts to approximately five feet. The beds exposed here are thicker and contain many more fossil remains than at the first rapid—The fossils are principally large trilobites and corals, as in the following list: *Spirifer crispus*; *Reticularia septentrionalis*: *Salpingostoma boreale*; *Diaphorostoma perforatum*; *Phragmoceras lineolatum*; *Illænus* sp. indet.; and *Bronteus Ekwanensis.*

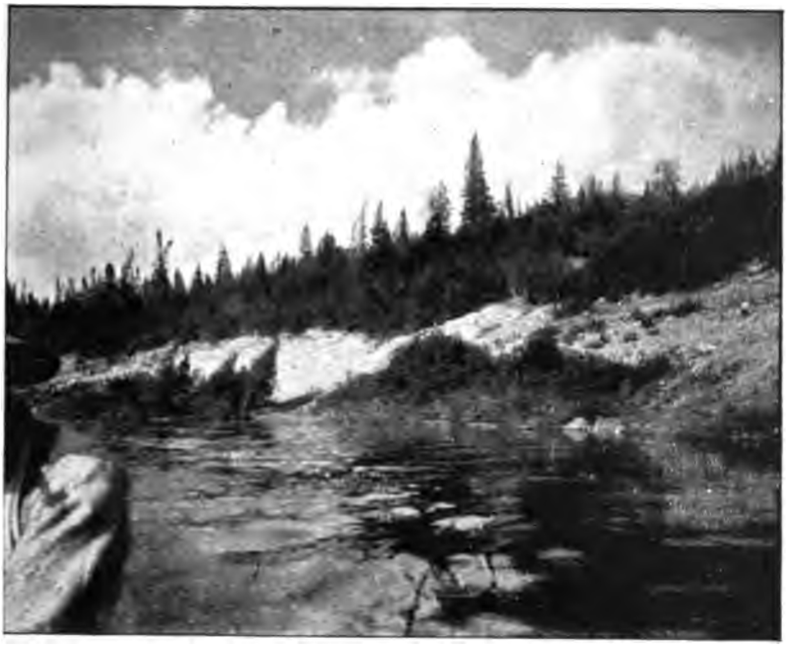
Above this the banks gradually rise in a series of steps to thirty feet, which might be taken as an indication of an old shore line.

The portage mentioned above is on the northern side of the river. Here the stream has cut a shallow gorge through the limestone. This has been slowly widened, and is the first indication of age that the river, thus far has shown. Below this, from the sea up stream, the river-channel is new—that is to say, it is still wearing down the sides of the valley and is bordered by cut-banks. The material thus fed into the river is being rapidly removed, and there is little of it deposited till the sea is reached.

Similar to limestones on Attawapiskat river.

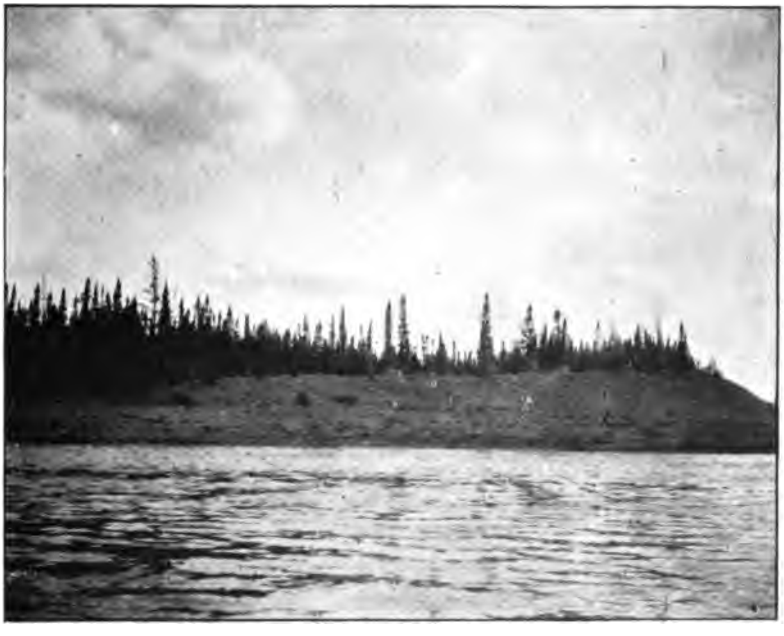
The rapids below the portage show a certain amount of river wear, but not so pronounced as at the portage. The beds out are not deposited in a regular manner, but are disarranged owing to the local development of coral reefs, which give the immediately overlying beds the appearance of having been disturbed and bent. These same limestones on the Attawapiskat river, just to the south, are described by Dr. Bell as cavernous limestones. It would seem that the more porous, or what seem to be the coralline masses, weather much more easily than the thinner beds. On this river there are no caverns, as the valley is not eroded deeply enough to expose much of the rock. The beds below the coral reef at the portage are thin and lying nearly horizontal, but above the portage the beds are thicker and contain a very numerous assortment of remains of gastropods and corals. The collections made here for the purpose of determining the horizon were mostly from the rocks near the upper end of the portage road. The list of species determined or described by Dr. Whiteaves, and published as a supplement to this report, in his opinion indicates a horizon rather high up in the Silurian.

Those which occur at this part of the river are given in the following list:—



D.B.D. Photo. 1901.

Landslides on outer bends of Ekwan River.



D.B.D. Photo. 1901.

Gravel piled on upper end of island, Ekwan River. Effect of ice shoving in spring freshets.

Halysites catenularia; *Lyellia superba*; *Zaphrentis Stokesii*; *Pycnostylus elegans*; *Pycnostylus Guelphensis*; *Favosites Gothlandica*; *Favosites Hisingeri*; *Stromatoporoid* sp. indet.; *Crinoidea* sp. indet.; *Fenestella subarctica*; *Trimerella Ekwanensis*; *Strophodonta* sp. indet.; *Plectambonites transversalis*; *Spirifer* sp. indet.; *Reticularia septentrionalis*; *Meristina* (?) *expansa*; *Reticularia* sp. indet.; *Glassia variabilis*; *Atrypa reticularis*; *Camarotœchia Ekwanensis*; *Ambonychia undulata*; *Ambonychia septentrionalis*; *Mytilarca pernoides*; *Ctenodonta su bovata*; *Euomphalopterus* sp. indet.; *Megalomphala robusta*; *Salpingostoma boreale*; *Gyronema speciosum*; *Gyronema Dowlingii*; *Gyronema brevispira*; *Loxonema* sp. indet.; *Orthonychia obtusa*; *Platyceras compactum*; *Strophostylus amplus*; *Strophostylus inflatus*; *Strophostylus filicinctus*; *Endoceras* (or *Nanno*) sp. indet.; *Kionoceras cancellatum*; *Orthoceras Ekwanense*: *Orthoceras* sp. indet.; *Phragmoceras lineolatum*; *Illænus* sp. indet.; *Bronteus Ekwanensis*; *Bronteus aquilonaris*; and *Ceraurus Tarquinius*. List of fossils.

For nearly four miles above the portage the current is swift and several small rapids occur, the largest of which has a fall of three feet. At thirteen miles from the portage is another rapid where the exposed rock is a thinly bedded limestone in a low anticline, the axis of which runs N.E. and S.W. A steady swift current is met all the way to Flint rapid, thirty miles above the portage, but the banks are in places partly overgrown with grass and the edge of the slope fringed with willow. Both species of poplar begin to make their appearance, and some trees are of fair size. In the lower reaches the banks are for the most part bare and clay, with boulder pavements near the stream.

All the exposures of the clay contain marine shells near the top, from which the following species were collected:—*Saxicava rugosa*, *Mya truncata*, *Macoma calcarea* and *Cardium ciliatum*. Marine shells.

No definite boulder clay was seen, as it is covered by the marine clay and the constant sliding from the surface conceals the underlying beds.

The Flint rapids are not more pronounced than many of the others, but as the river has cut partly through a series of beds of yellowish gray limestone, in which there are many inclusions of chert, the Indians have named the rapid “Piwana powestik” or Flint rapid.

The country on either side is about ten feet above the stream. Poplar shows in spots and occasionally clumps of large black spruce, but these are generally on the islands or prominent points of the river banks.

What is called Upper or Last rapid is a small fall of two feet, nine miles above Flint rapid, where the river flows over thin beds of lime- Fossils collected at Last rapid.

stone. The section of the rocks exposed consists of only a few beds, making a total of about six feet. The lower members are ashy gray in colour, somewhat mottled, and break into irregular lumpy fragments. A few fossils collected from these beds are given in the following list, from the appendix by Dr. Whiteaves.

Zaphrentis Stokesii; *Favosites Gothlandica*; *Orthis* sp. indet.; *Pleurotomaria* sp. indet.; *Actinoceras Keewatinense*; *Phagmoceras lineolatum*; *Isochilina* or *Leperditia* sp. indet.

The central beds are yellow and full of cavities of irregular shape, with a thickness of perhaps two or three feet. The top beds are gray and similar to those at the base. Fossils are scarce.

Above the rapid to the mouth of Little Ekwan river, the valley is probably slightly older than below, and the banks are covered with willow and poplar. The channel is wide and dotted with numerous islands. In a few places side channels form large islands and the current in this part is much slower, averaging only about a mile and a half per hour.

Little Ekwan river.

The Little Ekwan enters from the north in a narrow valley. The stream appears to be very small and is reported to be blocked by drift timber and windfalls, so that the Indians do not travel on it with canoes. Just to the south is the mouth of the Wagakashi coming from the south in a valley which is a continuation of that of the Little Ekwan. Another stream from the south, the Matiteto, enters three miles above the Little Ekwan and there are several places in the stream between these two points where the current is swift. Here the river has cut a channel through thin bedded limestone and about a foot of this shows on the banks. It is a fine-grained yellow limestone and shows no fossils. Three miles above the Matiteto, the same beds apparently, are also cut by the channel of the river, and this is the highest point on the river where we saw the underlying rocks. These exposures no doubt formed rapids in the earlier history of the channel, but they have since disappeared, and the general grade of the river is now nearly reached, except at one or two points. Similar denudation is observed at Flint and Last rapids, but, as there is a heavier bed of limestone to cut through, there is still a large amount of work for the river to do. At the portage and the series of rapids in that vicinity the rock is in thicker masses, consequently the falls are in the midst of the rock exposures.

Denudation.

Above the mouth of the Matiteto a higher terrace is reached and through this an older valley, opening to the east in a wide mouth is entered. The eastern face of this terrace and the sides of the old valley show sandy deposits which are probably the shore deposits when the sea flanked the eastern edge of this plateau. Their nature was not worked out, owing to lack of time, but there is little doubt that beaches may be found in this vicinity. Through the old valley the river is now cutting another channel and for ten miles upward the stream is very active and is wearing rapidly through the clay. Above this the grade is not so steep and consequently the current is much slower. The immediate banks of the stream in many places do not reach the sides of the old valley, but the higher plateau is in view at many points and finally, before reaching the mouth of the Washagami, the river seems to be flowing in a much narrower valley with occasional cut-banks, apparently the old channel slightly deepened. The active part of the revived stream has not yet reached the underlying rock, and its work is retarded by an occasional accumulation of boulders. About six miles below the Washagami a sudden bend of the stream to the south has thrown the current against the south bank, and excavation on a large scale is going on in this locality.

River cutting another channel.

The high plateau here entered, as well as its eastern slope to James bay, is covered by a coating of marine clay which probably overlies boulder clay. That some of this exists beneath the marine clay is proved at only one or two small exposures. It probably, in many places, contains no boulders and therefore the dividing line between it and the marine clay is hard to define. The reddish clay near the mouth of this river, although mainly free from boulders, appears to have received its colouring matter from a soft red shale which, though not outcropping on the bank may occur in the bed of the river below the limestone. This may be a local development of the boulder clay, as were it a part of the marine deposit a more extensive distribution might be expected. Large boulders are not numerous in the river channel, but at intervals there are accumulations of them. Small rounded boulders and pebbles are common, but the majority seem to come from the surface of the clay or the upper part of the section. Marine shells were collected from the banks near the top of the exposures, and these are of the same species as those recorded on a previous page as having been found near the mouth of the stream. The same species were also collected from the higher parts of the plateau at an elevation of four hundred feet above tide, showing that all this region was submerged at the close of the glacial period, to at least between four and five hundred feet. The uplift since then has been greater perhaps in the northern part of this area than in that to the south near the height-of-land. This differential uplift is clearly shown in the area to the west formerly covered by the glacial Lake Agassiz, where the highest

Plateau covered with marine clay.

Differential uplift.

beach at the north-east corner of the Duck Mountains is now 350 feet above the outlet at Lake Traverse. The plain now drained by the Ekwan and Attawapiskat rivers, on its emergence from the sea, sloped northward, and the drainage probably took a northern direction to Hudson bay but, as the plateau reached an elevation approaching its present position, this slope was lessened and the streams were diverted toward James bay. The older portions of the river channel, which are situated in the higher part of the plateau, probably carried streams which found their outlet by uniting, and flowing to the north from the vicinity of the Little Ekwan river and thus through the deep valley in which is situated Sutton Mill lakes. The present general direction for both these streams is on nearly parallel lines running north-easterly, but making a decided bend to the east and east-south east from the vicinity of the Little Ekwan.

Slope of country towards James bay regular.

The surface of the plane or slope toward James bay is very regular, and the uplift and consequent retreat of the sea very uniform in its movement. A slight steepness in the slope at the rapids at an elevation of 100 feet above the sea might be accounted for by a short halt of the sea margin at this line and consequent denudation. As the drainage on all this slope is new, the greater part of the surface is still very flat and swampy, as the minor drainage is not developed.

WASHAGAMI RIVER.

Washagami river.

The canoe route from the Ekwan river to Sutton Mill lakes follows a small branch from the north to the first small lake and thence westward, by a series of portages, to a stream flowing north to the lake. This branch, called the Washagami, is a small stream, very swift in its upper part and having a steady strong current all the way down to the Ekwan. Five miles from this stream it receives a tributary from the west, called the Nematagoi river, which appears to be nearly as large as the north branch which is supposed to be the main stream. Above this the water of the stream is clearer and comes from a series of lakes above. Several tributary brooks enter the valley but they are all apparently small. In the upper part, the stream meanders from side to side of a valley which it has formed. This is cut down about twenty-five feet and numerous exposures show stratified clay, with a few feet at the top of a sandy clay with pebbles. A few boulders in the bed of the river are apparently derived from the surface or upper part of the clay. Probably the majority are from the harder clay beneath, down to which the channel has been cut. Some of the steeper parts of the channel, where the current is also swift, are completely paved from side to side to side with these boulders, now considerably rounded. The valley in the lower part approaching the Ekwan is wider and the present channel of the river seldom reaches either side.

Fall of over two feet per mile.

In the distance traversed to the first lake, seventeen miles in direct line, the fall is about fifty-five feet or an average of over two feet per mile for the lower third of this distance, and this is increased in the upper to at least five feet per mile for a short distance.

On reaching the first lake it is quite noticeable that there is no longer a river valley such as in the lower part, but the lakes occupy a wider depression that may have been an old channel. The first one is Washagami lake and it is succeeded by a chain of three closely connected small lakes to another large one called Minago or Spruce lake. The first mentioned is said to be the largest or rather longest of the group. Beyond Minago lake lie Moss and Tamarack lakes. On the north side of the latter, high hills of black rocks, which are probably similar to the trap rocks of Sutton Mill lakes, are reported.

This series of lakes appear to lie in a valley now draining south, but it seems too large or wide to have been formed by the small stream now draining through it. The present stream has no doubt formed a new channel to the south of the lakes, as it is still very actively widening the bends where it touches each side of its own valley, but above this there is an older valley. The origin of this, as well as of the valley of Sutton Mill lakes is no doubt connected with the early system of drainage, now probably diverted into other channels by the differential uplift of the coast.

Portage route from the Washagami to Sutton Mill lakes.

The portage route from the Washagami to Sutton Mill lakes is mainly along the surface of the higher plateau through mossy muskeg interrupted by a few small lakes all draining eastward to the Little Ekwan river. Leaving the Washagami, the trail runs northward nearly a mile through muskeg, rising steadily to a gravel ridge having the appearance of a beach ridge. This is followed a mile to the north-east to the first small lake. On the north side of this ridge are several small lakes which all drain to the east from one to the other. At these lakes two short portages are made and then the second long portage is reached. This is about a mile and a quarter long through lumpy mossy muskeg and only one slight rise is crossed where the ground is dry. It ends at a small lake about 500 yards long with low margin. From the north-east end of this, another long portage of about the same length running east north-east reaches the western edge of a deep valley running north to Sutton Mill lakes. This contains a small stream from the north-west which has cut a deep narrow gorge through the boulder clay. This stream enters the valley at Sutton Mill lakes about two miles south of the lake and meanders back and forth through a marsh at its border. The stream is navigable for canoes from the end of the trail or for that part of its course which is in the deeper valley. Several small rapids over gravel bars are passed before the stream reaches the marsh. The Indians have erected a fishing weir at one of the upper ones. This structure is merely a close fence made of poles standing across the stream having a basket at one side also of poles sloping slightly up from the water to imprison the fish as they are going down stream. Small fish pass readily either way, but the larger ones are caught.

Timber in valley larger.

The timber in the valley is very much larger than on the surface of the plateau. Black spruce and tamarack are the principal trees, and on the plateau these average about four or five inches, but in the valley near the lake several about twelve inches in diameter were seen. The surface is nearly everywhere covered with moss, even on the slopes of the valley, and only in occasional places was grass seen.

SUTTON MILL LAKES.

Sutton Mill lakes.

These are represented on the older maps by two fairly large wide lakes joined by a short small stream, whereas the lakes are long and very narrow, occupying a deep valley running north and south. At the south end another valley from a short distance to the west makes a bend to the east and joins the main one. The water of the lake is about 100 feet below the level of the bordering country. The slopes of the valley are steep and in many places show cut-banks of marine clay, probably overlying boulder clay. Marine shells were collected near the upper surface of the plateau at a height of 90 feet above the lake, so that practically all this area has been submerged with the exception perhaps of a ridge of trap-covered rocks which cross the lake at the narrows. Those rocks protrude through the clay plain in rounded oval ridges.

Marine shells prove submergence of plateau.

The depth of the valley below the general surface seems to be greatest in the southern lake where, by sounding, the water was found to be 210 feet deep, or a total depth for the valley below the surface of 310 feet. In the northern part, or the northern lake, the width is much narrower, but the depth in the centre runs from 100 to 160 feet or 250 to 260 feet below the general surface. In the narrows the cliffs are broken down and the debris has filled the channel, raising the water in the southern lake about five feet. The heavy mantle of drift has effectually concealed the rock, and only in the river valleys and in such a cut as this is much rock to be seen. The limestone of the Ekwan river does not come north to the lakes, as outliers of the trap hills occur just to the south of the lake in the valley into which the trail from the Washagami leads. In the northern lake, past the trap hills, limestone again appears, and an exposure of it occurs on a small island where there is about ten feet exposed. Below the water-level the cliff is abrupt to a depth of sixty feet. · This shows that probably the Silurian deposits surround the Cambrian, but are at a lower level. The valley, although excavated through the superficial deposits, found as its lowest level a former break not only through the Cambrian at the narrows but also a deep cleft in the limestone beds to the north. In the valley which runs northward from the lake, the limestone beds cross the present river channel at a greater elevation above the sea than the cut through them in the lake valley.

Rocks concealed by drift.

As to the origin of the valley in which the lake lies, it seems to be clearly caused by the action of a stream, which in some manner has since been diverted, probably to flow eastward to James bay.

Origin of valley.

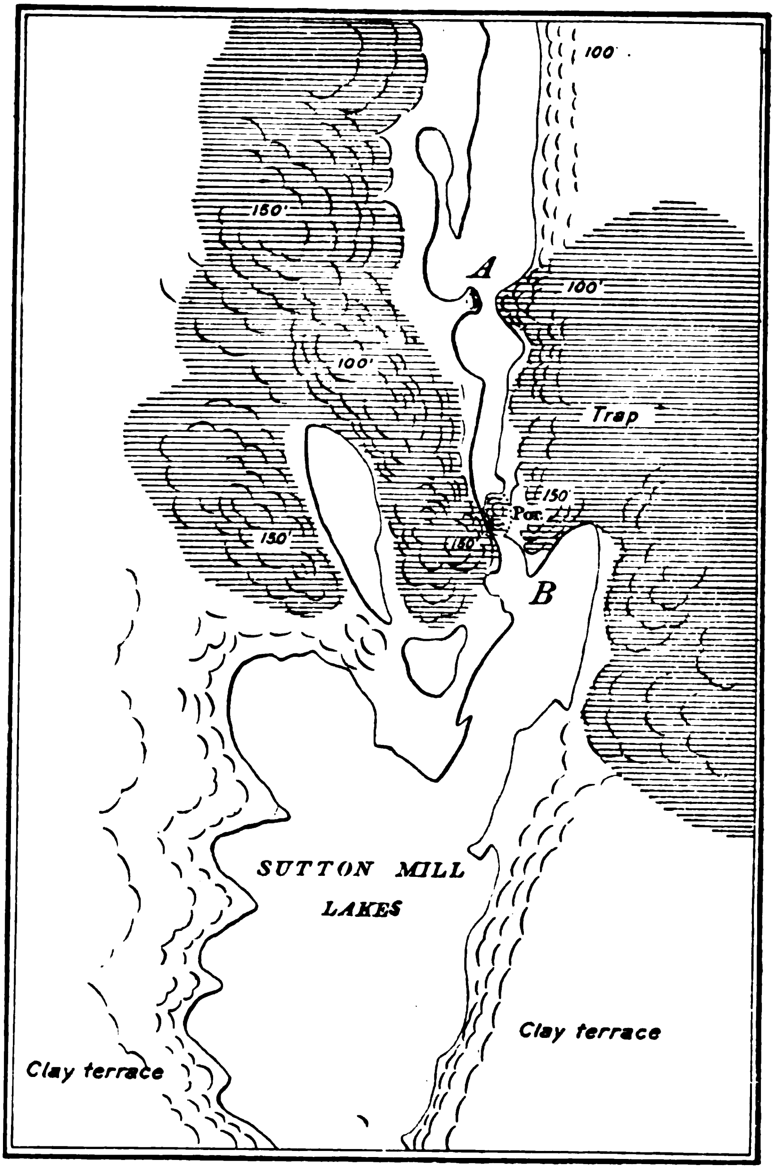
If the rising of the land was inaugurated in the southern part and gradually proceeded north as the pressure of the glacial mass was removed, then the general slope northward would have been steeper in front of the elevated portion and drainage channels would follow in this direction forming valleys trending north. After the elevation was accomplished or the land assumed its present contour, parts of these valleys would be so tilted as to back up the contained streams and cause them to spill down the present slight incline to the east. In this way it seems probable that such streams as the Ekwan and Attawapiskat, which make a decided turn to the east from a point south of this lake, might have originally run northward to Hudson bay. In the description of the Ekwan river the difference in age of the upper and lower parts of the valley is noted and also the supposition that the stream left its present valley near the mouth of the Little Ekwan.

Differences in age of Ekwan river valley.

The great depth to which the basin is eroded may be due to other causes, and one suggested by the presence of faults at the narrows is that the changes of level to which the crust has been subjected caused a great fissure to open along the line of the lake valley and a portion of the overlying deposits was thus allowed to drop down. If however, this was the chief cause, the break would probably be traced for a greater distance than the length of the present lake valley.

Rock exposures at the narrows.

The rock exposures occur principally at the narrows, or near the small stream connecting the two lakes. Approaching this from the south, the clay slopes give place to rocky hills rising from the water, in



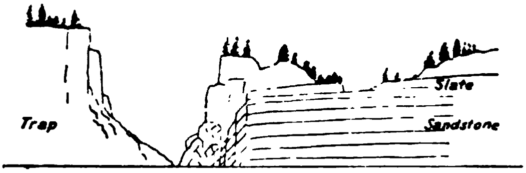
steep slopes and nearly bare surfaces, to about 100 feet above the lake level. Back from the lake ; some of the hills seem to attain still higher elevations, of probably over 200 feet. The sketch-map on the opposite page shows the trap-crowned hills of this vicinity. On the east side a series of fine-grained compact red and black beds is exposed, on the west the exposures are of trap to the water's edge. The fault, which runs north and south, here has a downthrow to the west of over 50 feet, carrying all the stratified lower rocks beneath the lake level. The only sections of these beds to be seen are on the east side, principally in the vicinity of the portage. Just at this place a small cap of trap stands near the gorge and behind it, to the east, is a narrow valley not eroded as deeply as the cut at the stream, but only to the upper beds of the sandstone and slate. Through this valley the road for the portage passes, rising to about fifty feet between its extremities.

Iron-bearing slates.

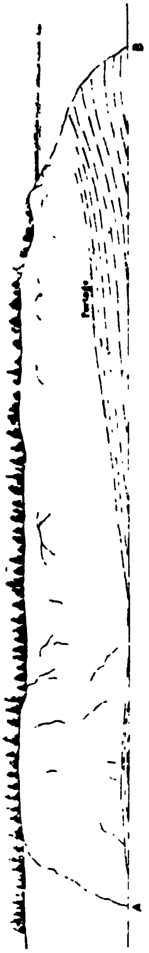
The highest point that the trail reaches is over a ledge of iron-bearing slates, above which on either hand rise the rough hills of trap. As the slates are nearly horizontal, the total thickness exposed on the portage road, together with that brought up by a slight anticline just to the south, represents all that was seen of these rocks. Northward the beds decline at a slight angle, so that they reach the water and are brought up again for a short distance at the second narrows, or the point marked A on the sketch. Here the fault runs to the west of the projecting point so that the same beds appear on both sides of the channel, but the western point is separated from the rocks to the westward by an accumulation of drift material forming a low spit with sandy bays on either side. The deep channel is eroded through the sandstones, to a depth of 140 feet. The section published in the summary report is that of the rocks to the south of the portage road. The jaspilytes when examined in thin section are found to be compacted sandstones, the grains of which are stained to various shades of red by the presence of iron oxide, which forms in many cases a coating around them All the beds are made up of fragments of various degrees of fineness arranged in a natural order, the coarser at the base and the finer at the top. The slaty beds just beneath the trap are made up of much finer grained particles of quartz, coloured dark by a matrix of opaque fine-grained material separating the grains. Some at least of this mass is probably magnetite. The quartz grains constitute 50 per cent of the mass, and of this about half are of red chalcedonic quartz and the other part clear grains made up of a mass of mosaic quartz. The red beds beneath are of much coarser grain, and are seen, even in a hand specimen, to be made up of rounded particles of red colours.

Jaspilytes.

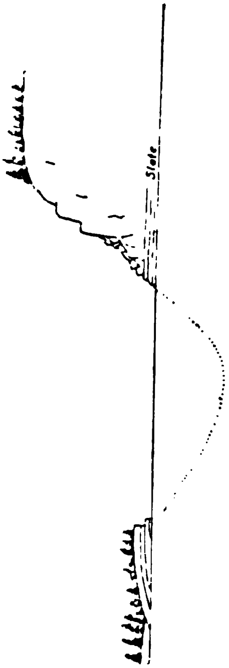
At point A the dark slates have a thickness of 20 feet, and below this the red beds begin to appear in thin streaks. The partings of the



CROSS SECTION AT B ON SKETCH.



SECTION FROM A TO B ON SKETCH.



CROSS SECTION AT A ON SKETCH.

fine-grained dark slates become thinner and the lower beds become red in colour.

At the portage the section consists of ninety feet of stratified beds capped by a varying thickness of trap. On the west side of the stream there is a thickness of about 150 feet. This is a dark green gabbro with a diabase structure. The predominating mineral is chlorite, with plagioclase, albite and quartz. Small dark almost opaque crystals of ilmenite surrounded by limestone, are occasionally seen. The slates beneath, to a thickness of 20 feet, are dark grayish black to greenish black and are thin-bedded and of fine grain.

An analysis gives 33.40 per cent metallic iron.

Near the base they resemble clay slates but are very hard and brittle, being cemented by the magnetite. An analysis of a specimen from this bed, furnished by Dr. Hoffmann, gives metallic iron 33·40 per cent, siliceous insoluble residue 48·49 per cent. The percentage of quartz increases downward in the section, and thin layers found at eighteen feet from the top are nearly all quartz. Some of the red beds near the top are somewhat crystalline in appearance, but on a polished surface the rounded grains are quite apparent. At 27 feet below the top, the rock consists is of a bright red, close grained jaspilyte, which in thin section shows well rounded grains of a bright red material, in all probability an eruptive, which was broken to a sand and cemented by quartz forming hard quartzite. The cementing quartz is in a fine mosaic and some of the red grains show minute cracks and sometimes a network of fissures which are filled by the same mosaic. In a few of the grains that have less of the colouring matter, the material is a reddish chalcedonic quartz with a dark red staining around the margin. At about 30 feet down in the section, the red sandstones alternate with dark rusty-weathering coarse slates. At 35 feet, the dark semi-crystalline beds are composed mainly of small particles of quartz and magnetite. The percentage of magnetite, as determined by Dr. Hoffmann, is very high—the metallic iron content being 68·62, the insoluble residue 4·21 with no trace of titanic acid. This would make a very good ore but it appears to be in very thin beds alternating with the sandstones. As all these ores have a very high percentage of silica, owing to the bands of sandstone, a reduction of this constituent might be had by selection or some mechanical process. From many of the beds between 40 and 50 feet in the section, thin members are found to be nearly pure magnetite, while the thicker beds are of the dark red sandstone containing less of the iron ore. A talus covers the section from 50 to 70 feet. Dark hard beds with narrow partings of slates similar to the top beds are found down to 80 feet. The lowest beds, or down to 90

Percentage of magnetite high.

feet, are very dark red sandstones of the same character as those above, but the outside of the grains and in many cases the whole individual is composed of the iron ore. An analysis of a specimen from the lowest bed exposed shows less iron than in the slates at the top; besides the lower members of this section are very hard. This rock contained metallic iron 27·72 per cent; insoluble siliceous residue 61·12 per cent. These samples are not specially rich in iron, but serve to show that the whole mass of this hill contains a large amount of low grade ore. The three samples analyzed are from the top, middle and bottom of the section.

Analysis of specimen from lowest beds.

On the small island in the northern lake a cliff of limestone was found. The beds exposed are somewhat similar to those seen on the Ekwan at the upper rapids. In this cliff there seems to be a great mass of broken fragments of corals and shells, mixed with what appears to be limestone fragments, the whole forming an agglomerate. The colour is an ashy gray. Beneath the water the beds are yellowish and of a finer grain. A few badly preserved fossils were collected, but among these Dr. Whiteaves has recognized or described the following species: *Zaphrentis Stokesii; Favosites Hisingeri; Phænopora Keewatinensis; Stropheodonta* sp. indet.; *Calymene Niagarensis* (?); *Encrinurus* sp. indet. Limestone fragments are numerous along the shores to the south of this, to within four miles of the narrows, and are derived no doubt from the beds beneath the water.

Timber.

In the southern lake, limestone pebbles are also numerous, but they are mixed with fragments of other rocks and are derived from the boulder-clay of the banks, while marine shells from the upper marine clay are also mixed with them. The timber seen along this lake is mostly spruce and tamarack. The heaviest growth is in the valley at the southern end of the lake, and along the small streams draining into it from the west. In going up the lake, the timber gradually becomes smaller, though at the portage between the two lakes, there is a fair grove of spruce, and a few poplars form a fringe along the southern slope and on the lower ground south of the narrows. In the northern part there is one grove of poplar on the western side, four miles north of the narrows, growing on a ridge which seems to be made up of lime-stone fragments and therefore well drained. This grove is quite park-like, it being carpeted by grass instead of the almost universal moss which seems to cover the whole country. The spruce is mainly the black species (*Picea nigra*) and scarcely any trees of the white spruce are seen. Of the poplar, both species are found on the

Ekwan, but on the lake *Populus tremuloides* seems to range farthest north. Near the north end of the lake the spruce trees become not only small, but are separated from one another by mossy openings, as if they had been set out artificially. Along the top of the bank the fringe of trees is thin and at the outlet, Trout river, a patch of burnt country will in a few years be bare.

Brook and lake trout plentiful.

The country seems to be nearly devoid of game, but the waters of the lake are well stocked with a slender kind of lake trout, and in the stream draining north and at the narrows, brook trout were found in large numbers up to three pounds in weight. Along the shores marine shells from the clays of the sides of the valley are found along with those of fresh water species now existing. These latter embrace the following:—*Valvata tricarinata*, Say; *V. sincera*, Say; *Planorbis parvus*, Say; *Limnæa stagnalis*, *L.*; *L. palustris*, *Muller*; and *L. catascopium*, Say; as determined by Dr. Whiteaves.

COAST OF JAMES BAY FROM EKWAN RIVER NORTHWARD.

Bars at mouth of Ekwan river.

In the bay into which the river empties there are many bars, but the main channel leads straight out to sea for a short distance and is then diverted north and south by a long bar which shoals at half tide. This bar is about three miles from low tide mark. There are two or three branch channels just at the mouth, through the gravel and mud delta, but these are used only when the tide is in. Along the shore to the point about five miles north of the river the general slope of the shore is fairly steep, that is, the mud flats do not extend out very far. The resident Indians call this point "Niahkow" (the sandy point), but it seems to be made up principally of mud and boulders with a sandy beach ridge at high tide. The boulder bar stretches out far to the east at low water. We saw it only at half tide and then had to make a long detour around it with the canoes. Several small brooks break through the ridge to the bay, and tent poles at these places indicate their occasional use as halting places or camps.

Timber line near the shore.

The timber line is here near the shore but runs at some distance back of the point from Niahkow northward; for about ten miles the shore is fairly straight but shallow, with few boulders on the mud flats. The beach ridge is separated from the timbered land behind by a narrow strip of mud, which in some places is covered by grass and a few small willows. A high gravel bar lying about a mile off shore marks the mouth of a small stream, which is an outflow from the Ekwan river. The stream is small and flows in a shallow sheet over the mud flats, so that it cannot be entered even by canoes except at high tide. Here the higher beach ridge is near the timber line and a mud flat extends out 200 yards to a second gravel ridge which has been formed in front by the high tides A lower ridge is now being formed in advance of this again, but it is covered by the highest tide. When the tide is out, it dries or uncovers to beyond the high gravel bar opposite, or to the north of the mouth of the river. The evening we arrived at this place, the Indians who were camped there pointed out to us a white object on the bar and by examination with the glass it proved to be a wandering white bear which had come ashore on a piece of ice. Our friends were rather nervous over the matter, but the animal had disappeared by morning, and the only other traces of this species were some tracks that were seen along the shore farther to the north.

Swan river

Northward from this brook there is a slight bend in the coast to the west to form a shallow bay and at about ten miles from the brook a fair sized stream called locally Wabishew Sipi (Swan river) enters the bay. The shore of this bay is flanked in many places by sand ridges, but as we passed at low tide we saw only part of the shore, and the mouth of the river being at a distance was hard to make out. As the shore here is backed by a uniform line of small spruce trees, varied occasionally by higher bunches or groups, a grove of poplar which shows on the left bank of the stream when opposite, is about the only indication of the presence here of a river. Northward from this stream the shore bends slightly to the east again, and a point sixteen miles north of the river is in the same longitude as the mouth of the brook which comes from the Ekwan river. At eight miles from Raft river, gravel bars that form small islands at half tide, run out from the shore to the southeast, and behind these the shore ridge for a short distance is wanting, and the mud slopes up gradually to a grassy flat. The tree line of small spruce follows the shore pretty closely for about fifteen miles north, but it then leaves the beach and turns to the north west.

The points are merely high gravel ridges, which are formed parallel to the shore in an irregular order. The intervals between are connected by lower ridges formings loops. Another series is also found in a few places near the tree-line belonging to an earlier set. Small streams are found running out by the gaps in the shore ridges and afford camping places between the mouths of the larger streams. At thirty miles north of the Raft river two high sand bars or small islands are again seen near the shore.

They are situated inside the tide-line and at low tide are not reached by the sea. Opposite, on the mainland, a narrow fringe of trees forms a point behind which the tree-line bears off toward the northwest. This may be the " Point Mourning " referred to by Capt. Coats, as being so named from the burying of one of Capt. James' men there. James' account does not mention this occurrence, and he appears to have landed on this coast only at Cape Henrietta Maria.

Mud flats make shore line difficult to determine.

Sailing along in a canoe, the shore-line seems very far away, but gulls, yellow-legs and other small birds were perched along on the edge of the mud and were the principal guide to the direction of the shore-line, as the mud flats look like smooth water, since there is always so much water draining down the slope.

Several large boulders appear at low tide at this point, and there are also two high gravel bars opposite the end of the trees. From Point Mourning northward, the shore turns about northwest as far as the Opinnagow river, and the beaches seen at high tide disappear and the slope of the shore becomes much flatter. Long shallow ridges of clay run out to the northeast, just after passing Point Mourning, and on these are scattered many boulders. The larger ones are frequently near the shore, but they do not seem to indicate having been shoved in any direction by the ice, as is so often shown on the shores of such shallow lakes as Lake Winnipegosis. The shore slopes upward very gradually, and is of mud to the highest point.

Opinnagow river.

At the margin of the ordinary tides a thick wiry grass covers the surface, and is succeeded by a small scrubby willow which extends back to the timbered country. Several brooks and small rivers enter the bay just to the northwest of Point Mourning. A stream called Nowashe river, at eight miles from the point, cuts a wide but shallow channel through the mud, but it is not deep enough to enter except at high tide and is probably an overflow channel from the Patchipawapoko, the next stream which comes in at about eleven miles from the point. The mouth at low tide is wide, but very shallow and dotted with boulders. The sand bars which have formed the beach, end before reaching this stream, and are succeeded by mud shores. These extend along for six miles between the last stream and the Opinnagow river, which is the largest along this part of the coast. The channel leading to this river is deeper at low tide than any of the others. Instead of a broad shallow bar at the mouth, the river is divided into two channels by a grassy island near the sea. That to the south is probably the larger, but is impeded by boulders. At low tide there is a shallow part near the line of high tide where the greatest accumulation of the boulders is found, but below this and out to low tide the boulders are less frequent. At low tide the entrance to this channel is two or three feet deep, so that a small boat could get in and come up the river as the tide deepened the channel. The main difficulty would be in finding the river at all, as there is so little to mark its position—the tree line being so far from the shore.

Along this part of the coast there are no bars visible at any distance from the land, as is the case along that part near the mouth of the Ekwan.

Navigation along coast not difficult for small craft.

Although the coast is very flat the navigation for small boats does not offer any great difficulties except from the want of harbours. Our guide thought that a small sail-boat could be taken into the mouths of Raft and Opinnagow rivers, and that as the shore was fairly free from boulders, the boat could if necessary be run ashore without damage at high tide and left in the mud.

The great objection to this method of finding harbour is in the fact that the tide does not maintain an even flow or ebb, being influenced to a very large extent by the direction and force of the wind. The ordinary flow of the tide may be assumed to be about six feet, but a heavy north wind may raise it to over twelve and a south wind will lessen the flow, though not to such a large amount.

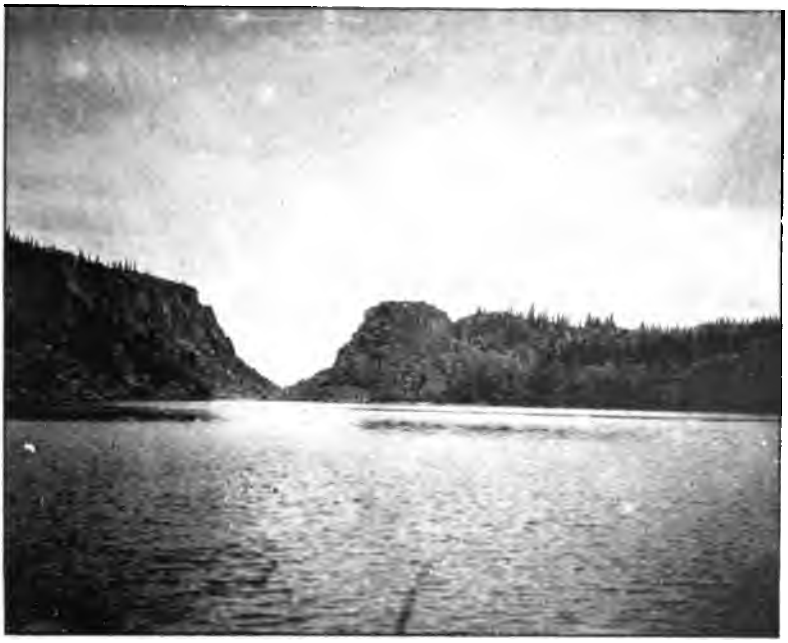
GEOLOGY.

The formations observed in the district consist of (1) the Cambrian rocks of Sutton Mill lakes; (2) the Silurian limestone bordering the west shore of James bay and the south shore of Hudson bay; and (3) the clays which form the general covering over nearly all the country left by the ancient glacier and the retreating ocean.

CAMBRIAN.

Rocks of Cambrian age similar to those on east coast of Hudson bay.

The rocks which are probably of this age are closely allied to those previously described by Dr. R. Bell and afterwards by Mr. A. P. Low on the east coast of Hudson bay and in the narrow belt of islands parallel to that shore—the Manitounuck, Nastapoka and Hopewell islands, and the narrow strip along the coast in the neighborhood of Manitounuck sound and at Richmond gulf. These were described by Dr. Bell in the report for 1877-78 pp. 11-19 c and called the "Maintounuck Group," and their similarity to the rocks of the Lake Nipigon region was pointed out.



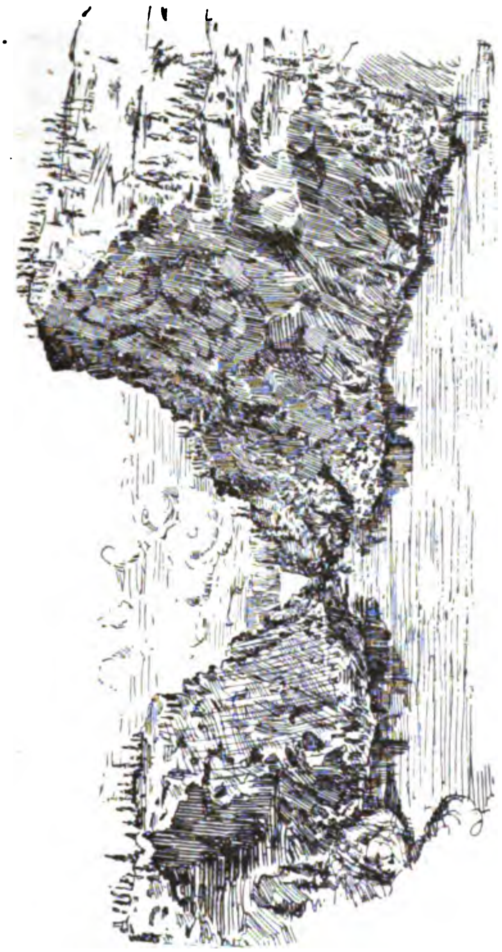
D.B.D. Photo. 1901.

Gap in Trap Hills at Narrows, Sutton Mill Lakes.

D.B.D. Photo. 1901.

Mud Flats, west shore James Bay, near Opinnagan River, looking shoreward.

The section there recorded, is in a general way, made up of quartz conglomerates, quartzites and sandstones. Associated with and overlying them is a series of cherts and shales, mostly dark colored. Overlying these beds is a heavy trap overflow and the total thickness of the series is placed at about 2,800 feet. This great thickness is not found [1] on the west side of the bay, however, but the upper part is probably there represented. The lower part is no doubt concealed by the Silurian limestones which are deposited along the margin, flanking it, not only along the Hudson bay side, but also to the south in the valley of the Ekwan river. The thickness of the marine clays and till which surround this rocky ridge, also conceals the underlying rock,



Drawn by P. M. Papineau.

THE GORGE AT PORTAGE BETWEEN SUTTON MILL LAKES, LOOKING SOUTH.

and it is only in such an erosion valley as that of the lake above referred to, that exposures of the beds beneath the trap can be seen.

Sandstones and slates impregnated with iron oxides.

In the vicinity of Sutton Mill lakes the series is nearly horizontal, inclining slightly to the north toward the basin of Hudson bay and as exposed consists of a thickness of 90 feet of sandstone and slates, capped by an extrusive trap showing a thickness of 150 feet. The sandstones and slates here, as well as on the Labrador peninsula, are impregnated with iron oxides chiefly in the form of magnetite and hematite. The sandstones exposed are composed of rounded and flattened grains of a reddish chalcedonic quartz surrounded by a slight deposit of the iron ore, and the interspaces are filled by a fine mosaic of quartz. In the darker coloured rock the grains are surrounded, and in parts replaced, by magnetite, while the interstitial quartz is less in amount. The appearance of the beds is that of a banded jasper, consisting of red beds separated by numerous narrow seams of a dark slate. On smooth surfaces the individual grains of the sandstone are distinctly shown. The slates which occupy the upper part of the section are made up of minute fragments of quartz, both red and colourless, forming 50 per cent of the mass, while the remainder is made up of a series of opaque particles which, from the result of an analysis of the rock, is probably largely magnetite.

Rocks similar to the Animikie of Thunder bay.

These rocks, when compared with those from the Animikie of Thunder bay, present many features in common. Their description as given by Mr. E. D. Ingall (Annual Report, Geo. Surv. Can., vol. III. p. 81 H.) shows that the general character is very much the same, but in the Sutton Mill lakes rocks the calcareous and dolomitic portions are wanting or have been replaced. The only mineral of economic importance observed in this series is iron. Magnetic ores of this metal are freely distributed throughout the whole of the section of the stratified series, but the fact that these ores are not generally concentrated in thick enough beds would count against their practical value. Closer examination might show that the richer parts of the section could be profitably worked. A few specimens from the exposure were brought in to the laboratory, and analyses of three were made. These are from the upper part of the section, the centre, and the lowest bed. The analyses of the three samples, as furnished by Dr. G. C. Hoffmann, are given below :—

From the upper bed—

Metallic iron...................	33·40 per cent.
Insoluble siliceous residue.......	48·49 "
Titanic acid......	none

Results of three analyses

From centre of the section—

Metallic iron..................	68·62 per cent.
Insoluble siliceous residue.......	4·21 "
Titanic acid....................	none

From lowest bed exposed—

Metallic iron	27·72 per cent.
Insoluble siliceous residue.......	61·12 "
Titanic acid........	none

The upper and lower beds represent the general mass of the sandstone and slate, the first being the slate of the beds just below the trap and not picked out as being an iron ore, while the specimen from the base of the section was of the dark red sandstone or jaspilyte, which showed streaks in which the magnetite made up a large percentage. The specimen from the centre of the section represents one of many of the richer beds in which nearly all the silica has been replaced by magnetite. There is a probability that thick enough beds of this ore could be found for profitable working, but their remoteness from the sea on, any near line of railway would render their present value in any case very doubtful.

SILURIAN.

Wide belt of limestone.

The valleys of all the streams entering the western side of James bay are cut down through the drift deposits to a flat-lying limestone, which forms a wide belt around the west shore of the bay and along the southern shore of Hudson bay. On the Albany river the upper part of the series is proved to be of Devonian age, and beneath, at a greater distance from sea, Silurian limestones are exposed. These beds probably overlap any older ones that may be beneath, and rest directly on the Archæan.

Rocks proved to be of age. Silurian.

On the Attawapiskat river Dr. Bell recognized the Silurian in the upper reaches of that stream, but a small series of fossils collected farther down, near the bay, seemed to present a Devonian facies, and the rocks of this age were then supposed to extend northward to this river. The collection of fossils from the portage on the Ekwan river was as complete as we could make it in view of this fact. Many of the species formerly collected both from the Attawapiskat and the Severn rivers were of forms apparently new to science or undescribed, so that their value as horizon markers was not very great. My collection embraced many more species and some in a good state of preservation, so that Dr. Whiteaves had no difficulty in deciding at once that they were not

Devonian but Silurian and that the species brought from the Attawapiskat river were in a great measure duplicated in this collection.

Devonian rocks confined to southern part of James bay.

It seems therefore certain that the Devonian rocks are confined to the southern part of James bay and the adjacent country, extending a short distance north of the Albany river. On the Severn river Mr. Low collected fossils which appear to be of Silurian age.

The section of the Ekwan appears to be nearly horizontal, or the beds exposed in ascending the stream seem to be in an ascending series. The first appearance of the underlying rocks noted in ascending the stream is a colouration in the boulder clay, probably from a red shale in the bed of the river Exposures of this were not seen, but higher up at the first heavy rapid, limestone of a gray to whitish colour in lumpy beds outcrops both below and at the rapid. The beds are very hard and dolomitic and contain very few fossils. At the next rapid the beds are yellowish and appear in thinner layers and of finer grain. The thickness exposed at both these rapids does not appear to be of any great amount, probably not over 20 feet.

The exposure at the portage is of a very irregularly bedded limestone, owing to the presence of large masses of porous or coralline formation, which has formed a very irregular surface for the succeeding layer which in consequence seems contorted. Below the coralline mass the beds are thin and of fine texture. The general colour is a grayish white and the rock is hard, tough and massive, and contains a greater variety of fossils than at any of the other exposures. Lists of the species found at these several rapids are given in the general descriptions for the localities. All the exposures at the rapids above this have a very similar appearance, except that in the exposures near the last rapid of this series the lower beds are fragmental, or break with a lumpy surface and are ash gray in colour. Above these are yellow beds, in which there are numerous irregular cavities. The ashy coloured beds bear a very strong resemblance to the Devonian rocks of the south shore of Lake Winnipegosis, but do not hold different fossils from those at the portage on this river. The yellow beds which are full of cavities are similar to rocks of Silurian age on Cedar lake in the Saskatchewan district.

Other exposures of these beds occur to the north of the Cambrian rocks of Sutton Mill lakes, and are found very near them so that the continuity of the series around this mass both by the south to the Severn river and to the east by the coast is almost certain. On the extreme end of the eastern point at Cape Henrietta Maria, our Indian guide described exposures of what seemed undoubtedly to be limestone of about the same characteristics as that on the Ekwan river.

POST TERTIARY.

Glacial striae recorded.

On all the rock exposures in the country adjacent to the Ekwan river, where the exposed surfaces have not been subjected to denuding agencies, glacial striæ have been recorded showing a movement of the ice mass toward the southwest. Only one exposure on the Ekwan showed such a striated surface, and this gave S. 40° W. All or nearly all the surfaces exposed in the valley were eroded by river action and the scouring effect of ice in the spring floods, so that the original glacial striae were obliterated. The till left by this ancient glacier is deposited in an even mantle over the surface and contains a few boulders, but the fragmental portions of the mass are of small size The depression of the earth's surface, owing to the weight of the ice sheet, is shown by the presence of marine clays on the surface of the boulder clay, and as these are of nearly the same composition as the clays beneath, the line of demarcation is hard to define. The marine clays extend up the Ekwan river to past the mouth of the Washagami and northward to and surrounding the ridge of trap which protrudes through the plain at Sutton Mill lakes. The extreme limit of submergence in the district to the south is given by Dr Bell as 500 feet. Near Sutton Mill lakes the top of the marine terrace now stands at 400 feet above tide, so that the submergence of the present coast line was greater than this amount. The fossils which determine these clays include the following species: *Saxicava rugosa*, *Mya truncata*, *Macoma calcarea* and *Cardium ciliatum*.

Limit of submergence.

APPENDIX I.

Preliminary list of fossils from the Silurian (Upper Silurian) rocks of the Ekwan river, and Sutton Mill lakes, Keewatin, collected by D. B. Dowling in 1901, with descriptions of such species as appear to be new.

BY J. F. WHITEAVES.

*ANTHOZOA.

TETRACORALLA.

Zaphrentis Stokesii, Edwards and Haime.

Ekwan river: portage road at falls, two specimens; and upper rapid, two specimens.

Small island in the northern of the two Sutton Mill lakes: four specimens.

Pycnostylus Guelphensis, Whiteaves.

Ekwan river: portage road at falls, one specimen; and foot of portage road, one specimen.

Pycnostylus elegans, Whiteaves.

Ekwan river, portage road at falls: one specimen.

HEXACORALLA.

Favosites Gothlandica, Lamarck.

Ekwan river: foot of portage road, five specimens; portage road at falls, one specimen; and upper rapid, one specimen.

Favosites Hisingeri, Edwards and Haime.

Ekwan river: lower rapid, one specimen; foot of portage road, one specimen; and portage road at falls, one specimen.

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* The Anthozoa have kindly been determined by Mr. L. M. Lambe.

Small island in the northern Sutton Mill lake ; one specimen.

This species occurs also in the Niagara and Guelph formations of Ontario.

OCTOCORALLA.

Halysites catenularia, L.

"The typical form, as identified by Canadian and United States palæontologists, under this name or that of *Catenipora escharoides*, Lamarck, and *C. agglomerata*, Hall." Lambe.

Ekwan river, foot of portage road: one specimen, that, according to Mr. Lambe, is like specimens from the Niagara and Guelph formations of Ontario and from Division 4 of the Anticosti group of Anticosti.

Lyellia superba. (= *Trematopora superba*, Billings.)

Ekwan river, portage road at falls: one specimen.

HYDROZOA.

Stromatoporoidea, genera and species undetermined.

Ekwan river, portage road at falls: two fragments, which seem to be referable to different genera.

ECHINODERMATA.

Crinoidea, genera and species uncertain.

Ekwan river, portage road at falls: a cast of the interior of a dorsal cup, that shows little more than the general shape and the impress of a few large hexagonal plates. Foot of portage road: two portions of finely annulated columns, which are circular in section and perforated by a pentalobate axial canal.

POLYZOA.

Fenestella subarctica, sp. nov.*

Zoarium spreading, somewhat fan-shaped, but probably funnel shaped when perfect. Branches very slender, carinated on the celluliferous face, and averaging from a fourth to a third of a millimetre in thickness. Bifurcations very infrequent in the only specimen collected, occurring at intervals of five mm. or more. Interstices much wider than the branches. Dissepiments about one mm. apart, or four and a half to five in the space of five mm. Fenestrules longer than wide, irregular but somewhat rectangular, nearly or quite a mm. long and approximately about half as wide as long. Zoœcial apertures circular, in two ranges, opening somewhat laterally, twenty in each range in the space of five mm., and three to four on each side in the length of a fenestrule, closely disposed but separate, slightly irregular in their disposition, sometimes alternate on the two sides of the keel, sometimes opposite, their margins indenting the borders of the fenestrules. Under a highly magnifying simple lens, the keel appears to be minutely spinose in places.

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*It is hoped that the new species described in this appendix, will soon be illustrated in one of the palæontological publications of the Survey.

Ekwan river, portage road at falls: one fairly good specimen. Mr. R. S. Bassler, of the U. S. National Museum, to whom the writer is indebted for critical suggestions in regard to the structural peculiarities, and affinities of this and the following species, writes that the zoœcial apertures of this *Fenestella* "seem unusually large, but this is due to the removal of the outer investment of the zoarium."

Phænopora Keewatinensis, sp. nov.

Zoarium bifoliate, branching, consisting of a thin flattened frond which is six millimetres wide on an average, but ten mm. wide at a bifurcation, and which bifurcates at intervals of about eleven mm. Zoœcia rhombic, a little longer than wide, seven in two millimetres measuring lengthwise and eight to eight and a half measuring transversely, divided by thin, straight longitudinal partitions, which form their sides and separate them into longitudinal rows. Apertures of the zoœcia obliquely oval. Surface marked by arching striæ, which curve convexly forward.

Small island in the northern Sutton Mill lake, one specimen. In regard to this specimen, M. Bassler writes as follows: It is "a *Phænopora* closely allied to several Clinton species, but which I should regard as new. In zoœcial structure is is very close to *P. multifida*, Hall, and especially to *P. fimbriata*, James. *P. multifida* has a differrent zoœcial growth and slightly larger zoœcia. *P. fimbriata* has about the same zoœcial measurements, but the growth of the zoarium is quite different."

Seven other species of *Phænopora* are known to occur in the Cambro-Silurian and Silurian rocks of Canada. These are: *P. incipiens*, Ulrich, from the Trenton limestone of Montreal; *P. constellata*, *P. ensiformis* and *P. explanata*, Hall, also *P. punctata*, Nicholson and

Hinde, from the Clinton and Niagara formations of Ontario; and *P. excellens* (*Ptilodictya excellens*, Billings), and *P. superba* (*Ptilodictya superba*, Billings), from the Anticosti group of that island.

BRACHIOPODA.

Trimerella Ékwanensis, nom. emend.

Trimerella Equanensis, Whiteaves. 1902. Ottawa Naturalist, vol. xvi, p. 141, pl. II, figs. 1 & 2, pl. III, fig. 1.

Ekwan river, portage road at falls: three ventrals and two imperfect dorsal valves.

The specific name is here slightly amended, in accordance with the more modern spelling of the name of the river.

Trimerella borealis.

Trimerella borealis, Whiteaves. 1902. Ottawa Naturalist, vol. xvi, p. 142, pl. III. figs. 2 & 3.

Ekwan river, lower rapid: a cast of the interior of both valves.

Stropheodonta, sp. indet.

Ekwan river, foot of portage road: one well preserved ventral valve, with the surface markings essentially like those of *S. varistriata*, var. *arata.*

Stropheodonta, sp. indet.

Small island in the northern Sutton Mill lake: two specimens, with the exterior marked by very fine, equal, radiating striæ.

Plectambonites transversalis (Wahlenberg).

Ekwan river, foot of portage road: two imperfect but characteristic ventral valves. In the Museum of the Survey there are specimens of this species from the Niagara group at Grimsby, Dundas, and Hamilton; from divisions 2, 3 and 4 of the Anticosti group, four miles west of Jupiter river, at East point, and at the Jumpers, Anticosti; also from the Silurian (upper Silurian) rocks of Lake Temiscouata, N.B.

Orthis, sp. indet.

Ekwan river, upper rapid: one half of the ventral valve of a small, rather coarsely ribbed and apparently undescribed species of the *O. Davidsoni* type. A similar but more perfect valve, in the

Museum of the Survey, was collected on the Fawn river, or branch of the Severn, by Mr. A. P. Low in 1886.

Camarotœchia Ekwanensis, sp. nov.

Shell small, moderately convex, transversely subelliptical and wider than long.

Ventral valve with an extremely small, narrow, erect or straight beak, behind, and a well defined mesial sinus, that extends backward to about the midlength, in front; the whole surface of the valve marked with thirteen rather distant angular radiating ribs, three in the mesial sinus and five on each side.

Dorsal valve with a still smaller beak, and with a fold corresponding to the mesial sinus of the ventral, its surface marked with twelve angular ribs, four on the fold and four on each side of it.

Hinge area and interior of the valves unknown.

Ekwan river, portage road at falls: one well preserved cast of the interior of the closed valves.

This small rhynchonelloid may possibly prove to be an extreme variety of *C. neglecta* (the *Atrypa neglecta*, Hall, of the second volume of the Palæontology of the State of New York) from which it seems to differ chiefly in its transversely and rather narrowly subelliptical marginal outline.

Atrypa reticularis, L.

Ekwan river, foot of portage road: two small specimens.

Glassia variabilis, sp. nov.

Shell very small, strongly compressed and lenticular in outline in transverse section, or moderately convex and varying in marginal outline from nearly circular and sometimes a little wider than long to subovate and a little longer than wide.

Ventral valve with the front margin either nearly straight and devoid of sinus, or faintly sinuated, or provided with a rather wide but not distinctly defined, shallowly concave or not very deep, mesial sinus, that extends backward to about the midlength. Umbo of the ventral valve small, narrow and not very prominent or produced, its beak slightly incurved and apparently perforate.

Dorsal valve with the umbo and beak smaller than those of the ventral.

Surface apparently smooth.

Spiralia directed toward the dorsal side (Schuchert); jugum, muscular impressions, and hinge dentition unknown.

Dimensions of a typical and average specimen (from the Winisk river): maximum length, slightly over eight millimetres; greatest width, eight mm. and a half; maximum thickness, four mm.

Two small loose blocks of limestone from or near the mouth of the Winisk river, collected by Mr. W. McInnes in 1903, are almost exclusively composed of nearly perfect shells of this species, many of which have the spiralia, or internal spiral cones, preserved. Some of the best of these specimens have been examined by Mr. Charles Schuchert, of the U. S. National Museum, who writes as follows in regard to them in a letter dated March 9, 1904. "The spiral cones in the Winisk shell are directed toward the dorsal side, but I cannot see the jugum. For the present I would refer it to *Glassia.* In external characters it is very near to *G. subovata* (Sowerby) but the difference in the spiralia will distinguish them, as the latter has the cones inwardly or medially directed. This difference is certainly of specific value, but for the present I should not regard it as of generic importance, as different genera of the Atrypidæ have the spiralia directed either laterally, medially or dorsally."

Ekwan river, foot of portage road, one specimen; Fawn river (or branch of the Severn), thirteen specimens; all of which are probably referable to this species, though none of them show any vestige of the spiralia or of any of the other characters of the interior of the valves. They are, perhaps, a little more convex proportionately than the typical form from the Winisk river. The sinus in each of their ventral valves seems to be a little more developed. In these respects the specimens from the Winisk are more like the *Atrypa compressa* of Sowerby, and those from the Ekwan and Fawn rivers more like the *A. subovata* of the same author, both of which are now regarded as forms of *Glassia subovata.*

Spirifer crispus? Hisinger. Var.

Ekwan river, middle rapid: one good specimen of a small radiately ribbed *Spirifer*, that is apparently similar, in size and general shape, to the *S. crispus*, as described and figured by European and American palæontologists, but which has narrow and angular, not wide and rounded ribs.

Spirifer (?) sp. indet.

Ekwan river: portage road at falls, one specimen; and at foot of portage road, one specimen; both casts of the interior of ventral valves that are possibly referable to *S. radiatus*, Sowerby, but that are much too imperfect and too badly preserved to be satisfactorily determined even generically.

Reticularia septentrionalis, sp. nov.

Shell strongly biconvex, but often with a faint, shallow, narrow longitudinal groove or depression in the median line of each valve; varying in outline in different specimens from subovate or somewhat pentagonal and a little longer than wide, to not far from circular and as wide as long, but always abruptly contracted and attenuate in the umbonal region behind; front margin of the valves straight and entirely devoid of a mesial fold or sinus.

Ventral valve with a narrow but prominent or produced umbo, a depressed, incurved and acute beak, and an extremely small delthyrium.

Umbo and beak of the dorsal smaller and less prominent.

Most of the specimens are little more than mere casts of the interior of the closed valves. Their surface is entirely devoid of ribs of any kind, and at first sight would seem to be marked only with concentric lines of growth. But, upon closer examination, numerous, obscure, close-set and very slightly raised concentric lines, or faint and minute, low, rounded ridges, can be detected on portions of the exfoliated test that happen to be preserved, and the shell structure, under a lens, is seen to be fibrous.

Characters of the interior of the valves unknown, though there are indications of a median septum in each.

Ekwan river: lower rapids, one specimen; middle rapid, one specimen; and portage road at falls, four specimens.

This large and nearly smooth species is provisionally referred to the genus *Reticularia* on account of its general resemblance to *R. modesta* (Hall), and *R. perplexa* (McChesney) which is the *Spirifer lineatus* of Shumard and other American palæontologists, but not of Martin; though it may prove to be a *Martinia*.

Reticularia (?) sp. indet.

Ekwan river, foot of portage road: two specimens, each of which has the whole of the dorsal valve and most of the ventral preserved, though the umbo and beak of the latter are broken off. Both are transversely subelliptical in outline and wider than long, and both have a rather shallow marginal sinus in the ventral valve. They are entirely ribless, but the better preserved one of the two is finely and nodosely cancellated by numerous, close-set, minute concentric ridges, that are crossed by similar radiating ones.

At the portage road at the falls a specimen, with the same general shape and with a similar sinus in the ventral valve, was collected, but it is so much worn that its surface markings are quite obliterated, and the beak of the ventral is so imperfect that it is impossible to tell whether it was originally perforate or not. This specimen seems to correspond fairly well with E. Billings' figures of *Athyris Blancha*, from the Silurian rocks of Maine, which Hall and Clarke refer to *Meristina*, but which Schuchert says is a *Meristella*.

Meristina (?) *expansa*, sp. nov.

Shell tumid, regularly and rather strongly biconvex, transversely subelliptical and always a little wider than long; front margin of the valves not at all sinuated; surface entirely devoid of any kind of ribs.

Ventral valve with a rather depressed though slightly prominent umbo, and an incurved beak.

Dorsal valve with a much more depressed umbo and a smaller beak.

Surface markings of the exterior of the test unknown, those of its exfoliated inner layer consisting of numerous, close-set and very minute, concentric raised lines, as well as of a few rather distinct concentric lines of growth; structure of the test fibrous.

Characters of the interior of the valves unknown, though there is clearly a long mesial septum in the ventral valve, and apparently a similar one in the dorsal.

Ekwan river: portage road at falls, one specimen; and foot of portage road, an unusually large but imperfect specimen. Attawapiskat river, seventeen to thirty miles below Rainy island, Dr. R. Bell, 1886: eight specimens.

These specimens are mere casts of the interior of the closed valves, with small portions of the inner layer of the test attached to some of them. It is by no means clear whether the beak of the ventral valve of any of them is perforate or not. They are provisionally and very doubtfully referred to *Meristina*, on account of their general resemblance in external form, to the European *M. tumida*, but it may be that they should rather be referred to *Meristella* or *Reticularia*. They seem to differ from *Reticularia septentrionalis* in their uniformly, transversely and broadly subelliptical contour, and in the more depressed umbo of the ventral valve of each.

MOLLUSCA.

PELECYPODA.

Ambonychia undulata (Whitfield).

Leptodomus undulatus, Whitfield. 1878. Ann. Rep. Geol. Surv. Wiscons. for 1877, p. 81; and (1880) Geol. Wiscons., vol. IV p. 293, pl. xviii, figs. 1 and 2.

Ekwan river: portage road at falls, an imperfect left valve; and foot of portage road, a nearly perfect and very convex right valve.

Both of these specimens are marked with "strong regularly rounded concentric undulations." Mr. E. O. Ulrich, who has kindly examined the five specimens of pelecypoda collected by Mr. Dowling, and to whom the writer is indebted for some critical suggestions in regard to them, thinks that *Leptodomus undulatus* is an *Ambonychia* allied to *A. planistriata*, Hall, and that the former had fine surface radii.

Ambonychia septentrionalis, sp. nov.

Shell obliquely and acuminately subovate or subrhomboidal, very inequilateral, rather strongly convex, most prominent in the umbonal region of each valve. Anterior side very short, abruptly truncated, or rather inflected, and flattened; posterior side a little longer, broadly rounded at its extremity and forming a subangular junction with the hinge line above. Umbones prominent, tumid but rather narrow; beaks incurved, anterior, and almost if not quite terminal; hinge line straight behind the beaks, equal to about two thirds of the greatest length of the valves beneath.

Surface marked with a few faint and obscure concentric undulations and lines of growth, also by extremely minute radiating lines. Test very thin.

Hinge dentition and muscular impressions unknown.

Ekwan river, portage road at falls: a cast of the interior of both valves, with part of the test preserved.

This shell is rather similar to the *A. affinis* of Ulrich from the Middle Galena of Minnesota and Illinois, both in its shape and surface markings. But, in the former the posterior end is more broadly rounded and not so much produced below, and the radiating raised lines of the surface are much more minute.

Mytilarca pernoides, sp. nov.

Shell compressed convex, rather obliquely subovate and very inequilateral, or broadly mytiloid and subalate behind. Anterior side very short, truncated or abruptly inflected above and rounded below; posterior side a little longer, its outer margin truncated somewhat obliquely and forming an angular or subangular junction with the cardinal border above, but rounded below. Cardinal border behind the beaks straight, its entire length equal to fully two thirds or more of the greatest length of the valves below; hinge area large; umbones apparently not very prominent; beaks appressed, incurved and almost terminal.

Surface marked with a few impressed and concentric striæ of growth; test rather thick.

Hinge with both cardinal and lateral teeth; muscular impressions unknown.

Ekwan river, portage road at falls: one testiferous left valve.

Mr. Ulrich thinks that this shell is "closely related to, if not quite the same as, *Ambonychia aphœa*, Hall," from the Niagara limestone of Illinois, which he (Mr. Ulrich) referred to *Mytilarca* in 1894, in the seventh volume of the Reports of the Geological Survey of Ohio. *A. aphœa*, however, was based upon a mere cast, which does not show the proportionate length of the hinge line, the size of the cardinal area, nor the surface markings, so that it is scarcely possible to make a satisfactory comparison between it and the specimen from the Ekwan river.

Ctenodonta subovata, sp. nov.

Shell small, inequilateral, moderately convex, subovate and one fourth longer than high. Anterior (?) side short and rounded; posterior (?) side produced, a little longer, and more narrowly rounded at its outer termination; ventral margin gently convex; superior border sloping abruptly downward in front of the beaks and much more gradually so behind them; umbones small and moderately prominent; beaks also small, incurved and placed in advance of the midlength; ligament external, short, placed on the shorter end of the hinge line.

Surface faintly, very minutely and concentrically striated.

Hinge dentition and muscular impressions unknown.

Dimensions of the only specimen collected: maximum length, twenty millimetres; greatest height, fifteen mm. and a quarter; maximum thickness, ten mm. and a quarter.

Ekwan river, portage road at falls: one testiferous specimen, with both valves.

The homologies of the shell of *Ctenodonta* are unknown, and it is not at all clear which is the anterior and which the posterior side of this species. If the shorter is the posterior side, as in *Nucula* and as would seem to be indicated by the position of the ligament, then the beaks of this species are placed a little behind the midlength and *vice versa*.

"In outline this shell agrees very nearly with my *C. simulatrix* and less closely with *C. Albertina*, but these species had the ligament on the longer, instead of the shorter end of the hinge." Ulrich.

GASTEROPODA.

Pleurotomaria (or *Euomphalopterus)* sp. indet.

Ekwan river, upper rapid: five badly preserved casts of the interior of the shell of a widely umbilicated species of *Pleurotomaria* or *Euomphalopterus*, with a very low obtuse spire. These specimens are very similar in shape to casts of *Pleurotomaria Valeria*, Billings, which is probably an *Euomphalopterus*, but the outer whorl of each is not so distinctly keeled at the periphery.

Euomphalopterus, sp. indet.

Ekwan river, foot of portage road: a specimen with the upper half of the shell completely worn away, the basal half, which is all that is left, being narrowly umbilicated and showing part of a peripheral alation.

Megalomphala robusta, sp. nov.

Shell large for the genus, strongly convex but deeply and rather widely umbilicated on both sides, the umbilicus occupying about one half of the entire diameter though its margin is not very distinctly defined. Whorls at least three and perhaps more, increasing very rapidly in size and laterally expanding, coiled closely on the same plane and everywhere in close contact, but with little or scarcely any overlapping; their periphery encircled by a continuous slit-band; exposed portions of the inner ones truncated almost vertically but somewhat obliquely on each side. Outer whorl rounded on the periphery in some specimens, faintly and obtusely subangular in others, distinctly subangular around the umbilical margin on both sides, the umbilical wall being steep but somewhat oblique. Slit-band narrow, in half-grown specimens moderately elevated and bounded on each side of its summit by a spiral raised line, but this minute double keel becomes obsolete on the outer half of the last volution, in adult shells. Outline of transverse section near the aperture subreniform and much wider than high in some specimens but somewhat triangular and nearly or quite as high as wide in others; outer lip not preserved in any of the specimens collected, but apparently not abruptly expanded; apertural slit unknown.

Surface of most of the specimens collected marked only with curved, transverse striæ of growth, but in one specimen the markings consist of small narrow, thin transverse ridges, with flat spaces between them.

Ekwan river, portage road at falls: seven specimens, all of which are imperfect at the aperture. The largest is seventy two millimetres in its maximum diameter.

The generic name *Megalomphala*, Ulrich, 1897, is, however, too close to *Megalomphalus*, Brusina, 1871.

Salpingostoma boreale, sp. nov.

Shell small, consisting of three rounded volutions that are a little wider than high and coiled on the same plane, in close contact, with little or no overlap, or at least closely contiguous if not actually in contact; umbilicus wide and open, exposing most of the inner whorls. Aperture trumpet shaped, lip widely and abruptly expanded.

Surface marked with minute rounded spiral ribs, that are crossed by small, crenate, lamellose raised ridges. The slit-band is not well shown in either of the few specimens collected, but it seems to be narrow, and continuous, at least at some distance behind the aperture.

Ekwan river: middle rapid, foot of portage road, and portage road at falls; one specimen from each of these localities. The largest of these specimens, though only twenty-three millimetres, or less than an inch, in its maximum diameter, has an abruptly expanded aperture. The other two are obviously immature shells, each about eleven mm. in its greatest diameter. In one of them the posterior half of the earliest volution is free from, and not quite in contact with, that which immediately succeeds it.

It is only in the continuity of the slit-band that this species and shells of this genus are supposed to differ from *Tremanotus*, or as Dr. Paul Fischer spells it, *Trematonotus*.

Strophostylus filicinctus, sp. nov.

Shell depressed turbinate and wider than high, spire rather short, less than half as high as the outer whorl, as viewed dorsally. Whorls six or perhaps seven, rounded but slightly flattened at the suture above, increasing rapidly in size, the outer one strongly inflated, ventricose and imperforate at the base. Aperture subcircular, lip thin and simple.

Surface marked with extremely minute and close-set, low, rounded, spiral raised lines, and by fine transverse striæ of growth. On the last volution but two of one specimen there are nineteen of these spiral raised lines, and four and a half in a millimetre. On the outer whorl of an apparently adult specimen, and near the aperture, there are three spiral raised lines to a mm.

Ekwan river, portage road at falls: two specimens, with the minute surface markings well preserved. One of these is a testiferous specimen with nearly the whole of the spire preserved, but with the outer whorl almost completely broken off; and the other a cast of the interior of the last two whorls of the shell of an adult specimen, with a small piece of the test preserved, at and near the aperture. Beside these there are four specimens that are probably referable to this species, though none of them show any trace of the minute spiral lines upon the exterior of the test. Three of these are from the portage road at the falls, and one from the foot of the portage road.

This species would seem to be congeneric with *Cyclonema cancellatum* of Lindström, from the Silurian rocks at Gotland, which Ulrich says is a *Strophostylus*.

CEPHALOPODA.

Endoceras (or *Nanno*) sp. indet.

Ekwan river, portage road at falls: two fragments of siphuncles, or of a siphuncle, that are presumed to be referable to either *Endoceras* or *Nanno*, on account of their apparent homologies with specimens collected by Dr. Ells and the writer in 1902 in the chazy or Black River limestone at Kingston Mills, Ont.

Actinoceras Keewatinense, nom. prov.

This is a provisional name for some peculiar, obliquely subnummuloidal and presumably submarginal siphuncles, or portions of siphuncles, somewhat resembling those of *A. cochleatum* (Schlotheim). They are longicone and increase very slowly in thickness, nearly circular in transverse section, and encircled, at more or less regular intervals, by narrow and rather deep, obliquely transverse constrictions. Between these constrictions the siphuncle is laterally compressed and but slightly expanded, while its tranverse diameter is from two to three times as great as the distance between the constrictions.

The surface makings of these siphuncles consist of fine close-set longitudinal striæ.

Rainy island, Attawapishkat river, Dr. R. Bell, 1886: three fine and rather slender specimens. Ekwan River, upper rapid: two distorted fragments.

The best specimen, from the Attawapishkat river, which shows ten of the siphuncular constrictions, is three inches and nearly a half in length, by twelve millimetres in diameter near the smaller end, and twenty-two near the larger. In this specimen the width of the siphuncle is about twice as great as the distance between two of the constrictions. In another equally slender but shorter specimen from the same locality, which shows seven siphuncular constrictions, the width of the siphuncle is nearly three times as great as the distance between the constrictions, at the smaller end; and only twice as great at the larger.

Kionoceras cancellatum (Hall).

Orthoceras cancellatum, (Hall). 1852.

Orthoceras columnare, Hall. 1866. Not *O. columnare*, Marklin, 1857.

Orthoceras Scammoni, *O. Hoyii*, *O. lineolatum*, and *O. irregulare*, McChesney, 1861; teste Hall.

Orthoceras Woodworthi, McChesney, 1865; teste Hall.

Orthoceras Cadmus, Billings. 1886.

Orthoceras angulatum, Hall. 1867. But not *O. angulatum*, Wahlenberg. 1821.

Orthoceras virgatum, Hall. 1867. Not *O virgatum*, Sowerby. 1839.

Orthoceras subcancellatum, Hall. 1877.

Orthoceras orus, Hall. 1877.

Ekwan river: portage road at falls, two fragmentary specimens, the largest less than two inches in length; and middle rapid, two similar fragments; all of which seem to be referable to this species. Each of these specimens is a portion of a longicone orthoceratite, with a circular transverse section, a central or nearly central siphuncle, and marked with narrow longitudinal ridges, separated by wider grooves or intervals, with minute, close-set, transverse, raised lines between them. Specimens with similar external characters have been found in the Niagara and Guelph formations at three localities in Ontario and Quebec. These are the *Orthoceras Cadmus*, of Billings, from

Grimsby and Elora; a specimen from Elora that the writer has referred to *O. Scammoni*; and a specimen from L'Anse à la Barbe, near Port Daniel, in the Baie des Chaleurs, in the Museum of the Survey, labelled *O. virgatum*, by E. Billings.

O. Cadmus, *O. subcancellatum* and *O. orus* are names that have been given to this shell on the assumption that Hall's *Orthoceras cancellatum* is not the same as the *Orthoceratites cancellatus* of Eichwald. Billings, in a paper entitled "New Species of Fossils from the Clinton and Niagara formations" and published with his "Catalogues of the Silurian Fossils of the Island of Anticosti", says that his *O. Cadmus* appears to be *O. cancellatum*, Hall, not Eichwald. And in the explanation of fig. 11, of Plate 19 (10) of the Twentieth Regents' Report, Hall says that the character of the surface of impressions of the exterior of specimens from Wisconsin and Illinois that he figures and refers to *O. angulatum* and *O. virgatum*, is "precisely like that of *O. cancellatum*, Hall, from the Niagara group of New York, and differs in no essential particular from the minute surface markings of *O. columnare*." But Dr. Foord has shown that Eichwald's *Orthoceratites cancellatus* is an *Endoceras*, and the specific name *cancellatum* does not appear to be preoccupied in *Orthoceras*, and certainly is not in *Kionoceras*. And if it be objected that "once a synonym always a synonym", then the next specific name to be selected would seem to be *K.* or (*O.*) *Scammoni*, if Hall's *O. cancellatum* is not the same as the *O. canaliculatum* of Sowerby.

Orthoceras, sp. indet.

Apparently brevicone; longitudinally ridged, ridges unequal in size and irregular in distribution.

Ekwan river, portage road at falls: a fragment that is not sufficiently long to show conclusively whether it formed part of a brevicone orthoceratite or not.

Orthoceras Ekwanense, sp. nov.

Shell increasing rather rapidly in thickness, compressed, elliptical in cross section; surface of the test smooth; septa very close together, siphuncle apparently central, though the internal structure is badly preserved in the only specimen collected.

Ekwan river, portage road at falls: one specimen, a little over two inches in length, and fully two inches in its longer diameter at the larger end. Perhaps a *Rizoceras*, which is possibly an inadvertent spelling of *Rhizoceras*.

Phragmoceras lineolatum, sp. nov.

Shell, or cast of the interior of the shell, apparently essentially similar to that of *P. Nestor*, as described and figured by Hall, in general shape and in that of its aperture, but with the exterior of the test marked with very numerous, closely and regularly disposed, minute transverse impressed lines, that give to the surface a minutely ribbed appearance, under a lens.

Ekwan river: middle rapid, a cast of the interior of a large body chamber; foot of portage road, one good specimen and three fragments; portage road, at falls, two good specimens and one fragment: and upper rapid, a large but imperfect cast of the body chamber and of nine or ten of the chambers between the septa.

The type of *P. Nestor* is a mere cast of the interior of the shell, with no indications of the surface markings of the test, and in *P. Nestor*, var. *Canadense*, there are remains of rather coarse longitudinal ribs.

CRUSTACEA.

OSTRACODA.

Isochilina or *Leperditia*, sp. indet.

Ekwan river, upper rapid: a rather large right valve about twelve millimetres long, but with only its interior exposed.

TRILOBITA.

Calymene Niagarensis ? Hall.

Calymene Blumenbachii, Billings, pars; but perhaps not of Brongniart.

Small island in the northern Sutton Mill lake: an imperfect head that is probably referable to this species, though it shows little more than a cast of the glabella, which is proportionately wider in front than that of average examples of C. *Niagarensis* from the Anticosti group of Anticosti. The Canadian Calymenes that E. Billings identified with *C. Blumenbachii* are now usually referred to four species, viz., *C. senaria*, Conrad, from the Trenton limestone; *C. callicephala*, Green, from the Hudson River group; *C. Niagarensis*, from the Niagara, Guelph and Lower Helderberg formations and from the Anticosti group; and *C. platys*, Green, from the Corniferous limestone.

Illænus, sp. indet.

Ekwan river: middle rapids, one pygidium; foot of portage road, three glabellæ and four pygidia; portage road at falls, one pygidium. The dorsal furrows of these three glabellæ are well defined, but the shape and position of the eyes or ocular lobes are not well shown in either.

Bronteus Ekwanensis, sp. nov.

Pygidium very large, attaining to a length of a little more than four inches and a little longer than wide, longitudinally and broadly subelliptical but truncated anteriorly, its posterior end being rather narrowly rounded and its lateral margin nearly straight on each side anterior to the midlength. Axis moderately convex, inversely subtriangular, longer than wide, with an obtuse apex, occupying more than one-third but less than one-fourth of the entire length of the pygidium and marked with a transverse groove near its anterior margin. Pleural region most prominent at and near the midlength of each of the pleural ribs, decreasing abruptly in convexity outward to the lateral margins of the pygidium, but much more gradually so to its posterior margin; marked by fifteen large flattened convex radiating ribs, with narrow grooves between them; each rib being narrow at and near the axis and wider at some distance from it, though all the ribs fade out at a short distance from the margin and before reaching it. The median rib is shallowly bifurcate posteriorly.

Surface apparently smooth. Cephalon and thoracic segments unknown.

Ekwan river: lower rapid one, imperfect pygidium; middle rapid, the largest and most perfect pygidium collected; and foot of portage road, one imperfect pygidium and two fragments.

Bronteus aquilonaris, sp. nov.

Pygidium of medium size, apparently not exceeding an inch and a half in width, transversely subelliptical and much wider than long, with an almost flat but slightly convex axis, and still flatter pleural region. Axis short, inversely subtriangular, with an obtuse apex and somewhat concave sides, nearly twice as wide as long, almost smooth but marked with one transverse furrow near the anterior margin; median rib a little wider than any of the lateral ribs and bifurcate posteriorly; lateral ribs seven on each side, straight and flattened convex, all of the ribs fading out before reaching the margin.

Surface apparently smooth. Cephalon and thoracic segments unknown.

Ekwan river: portage road at falls, three pygidia, each with the axis imperfect; and foot of portage road, one pygidium with the axis well preserved.

Bronteus Niagarensis, Hall, from the Niagara limestone of Ontario, has a much larger pygidium, with the midrib entire and contracted at its midlength, while the lateral ribs are wider and flexuous. *B. acamas*, Hall, from "limestone of the Niagara group at Wisconsin" and Ontario (which S. A. Miller says is a synonym of *B. occasus* of Winchell and Marcy) has a much larger and more pointed pygidium, with an "entirely simple" and undivided midrib. *B. insularis* of Billings, from the Anticosti group of Anticosti, is a diminutive species with a pygidium less than half an inch wide and wider than large; while *B. Pompilius*, Billings, from the Silurian (Upper Silurian) rocks at Port Daniel, has a small pygidium with a "longitudinal median lobe in the axis."

Ceraurus Tarquinius (Billings).

Cheirurus Tarquinius, Billings. 1863. Proc. Portland Nat. Hist. Soc., vol. i, p. 121, fig. 22.

Ekwan river: portage road at falls, and foot of portage road. At each of these localities two heads were collected, which seem to be essentially similar to the types of *C. Tarquinius*, from Port Daniel, in the Museum of the Survey, though the characters of the posterior angles of the cephalon of that species are still unknown. In the Ekwan river specimens, the eyes are opposite the second lobe of the glabella, the cheeks are coarsely punctured, and each of the posterior angles of the cephalon ends in a short spine.

APPENDIX II.

List of plants collected by Mr. D. B. Dowling at the mouth of the Ekwan and Albany rivers, 1891.

BY JOHN MACOUN, M.A., F.L.S.

Though Mr. Dowling only collected 41 species of flowering plants the collection is in several respects an interesting one. In the first place no plants had previously been obtained from the west coast of James bay as far north as the Ekwan river, so that the range of every species collected has been extended. No truly Arctic plants were obtained, but on the other hand there were several species which require a temperate climate. Among these are *Lathyrus palustris*, *Rosa blanda*, *Mertensia paniculata* and *Erysimum cheiranthoides*.

One of the most interesting plants in the collection is the rare *Pyrethrum bipinnatum* only found in Canada in the Hudson bay region. Other interesting species are *Primula stricta*, *Cypripedium passerinum*, *Carex turfosa*, and *Poa alpina*.

1. Anemone multifida, Poir.
2. Anemone parviflora, Mx.
3. Ranunculus circinatus, Sibth.
4. Braya purpurascens, Bunge.
5. Erysimum cheiranthoides, L.
6. Stellaria longipes, Goldie.
7. Lathyrus palustris, L.
8. Hedysarum Mackenzii, Rich.
9. Potentilla Anserina, L. Var. Grœnlandica, Sen.
10. Potentilla fruticosa, L.
11. Fragaria Virginiana, Duch.
12. Rosa blanda, Ait.
13. Rubus arcticus, L.
14. Heracleum lanatum, Mx.
15. Achillaea Millefolium, L., var. nigrescens, L.
16. Artemisia Canadensis, Mx.
17. Erigeron hyssopifolius, Mx.
18. Senecio Balsamitae, T. & G.
19. Senecio palustris, Hook.
20. Pyrethrum bipinnatum, Willd.
21. Taraxacum officinale, L.
22. Primula farinosa, L.
23. Primula stricta, Horn.
24. Mertensia paniculata, Don.
25. Pedicularis Grœnlandica, Retz.
26. Castilleia pallida, Kunth.
27. Pinguicula vulgaris, L.
28. Plantago maritima, L.
29. Cypripedium passerinum, Rich.
30. Habenaria dilatata, Gray.
31. Habenaria hyperborea, R. Br.
32. Sisyrinchium angustifolium.
33. Allium Schœnoprasum, L.
34. Juncus Balticus, Willd.
35. Triglochin maritimum, L.
36. Carex maritima, Mull.
37. Carex turfosa Fries.
38. Eriophorum polystachyon, L.
39. Elymus mollis, Trin.
40. Poa alpina, L.
41. Poa arctica, R. Br.

GEOLOGICAL SURVEY OF CANADA
ROBERT BELL, M.D., D.Sc. (CANTAB.), LL.D., F.R.S., I.S.O.

REPORT

ON THE

ORIGIN, GEOLOGICAL RELATIONS AND COMPOSITION

OF THE

NICKEL AND COPPER DEPOSITS

OF THE

SUDBURY MINING DISTRICT

ONTARIO, CANADA

BY

ALFRED ERNEST BARLOW, M.A., D Sc.

OTTAWA
PRINTED BY S. E. DAWSON, PRINTER TO THE KING'S MOST
EXCELLENT MAJESTY
1904

No. 873

To ROBERT BELL, M.D., LL.D., D.Sc. (CANTAB), F.R.S., I.S.O.
Acting Director, Geological Survey of Canada.

SIR,—I beg to transmit, herewith, my report on the Origin, Geological Relations and Composition of the Nickel and Copper Deposits of Sudbury, Ontario. The report also includes brief references to the character and extent of all the more important nickel deposits of the world, with a general statement of their production and methods of smelting and refining. Details of the mining, smelting and refining operations of the Sudbury ores are furnished, as well as complete statistical tables of production, prices, uses and composition of the nickel of commerce. It is believed that the report will serve to bring together in one volume, all of the more valuable and critical original investigations in regard to these immense and apparently inexhaustible deposits.

Canada has at last realized the true importance and value of these mines and has, within the last year, taken her position, from which she will not recede, of being the largest producer of nickel in the world. Hoping the present report will satisfy the demand which has existed for some time, for detailed and accurate information in regard to these ore bodies,

I have the honour to be, Sir,
Your obedient servant,

ALFRED ERNEST BARLOW.

GEOLOGICVL SURVEY OFEICE,
OTTAWA, JULY 4th 1904.

THE NICKEL AND COPPER DEPOSITS OF SUDBURY, ONTARIO.

BY

ALFRED ERNEST BARLOW, M.A., D. Sc

INTRODUCTION

Reasons for undertaking present work.

Ten years having elapsed since the appearance of the first official and detailed account of these famous ore bodies, (1) coupled with the fact of a renewed and even increased interest and activity in the mining of nickel, marked the time as most opportune, when another attempt should be made to arrive at a more accurate and complete understanding of the true nature and extent of these deposits which have proved such a valuable asset to Canada. Besides, the first edition of the map of the Sudbury Mining District, published in 1891, to accompany a report by Dr. Robert Bell on the geology of this area (2) had nearly all been distributed, and this in spite of the fact that the Bureau of Mines of Ontario had on several occasions issued special editions of practically the same geological map, to accompany the Annual Reports of their department, as, for instance, in the years 1892 and 1900. In addition, it was felt that although the general accuracy and usefulness of this map had never been questioned, it was lacking in certain details which are now known to be of the first importance and which are most essential for a proper interpretation and judgment of these deposits. Thus, on the first map, the intrusive mass with which the Chicago and Victoria Mines occur, is entirely separated from a band of similar rock along the southern borders of which the Gertrude, Creighton and North Star deposits are situated, whereas, it has now been ascertained that all of these properties are developed along the southern boundary of one large and continuous band, constituting the southern or principal belt of the nickel bearing eruptive. Again, on this first map, no distinction is drawn between the masses or belts of nickel bearing norite, and certain older hornblende porphyrites, diorites and green schists, which, although closely related to, and often resembling

Continuity of main mass of norite.

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(1) Ann. Rep. Geol. Sur. Can., Vol. V, part S, 1890-91, pp. 122-138.

(2) Ann. Rep. Geol. Sur. Can., Vol. V, part F, 1890-91, pp. 1-95.

the norite, are altogether barren of deposits of the valuable sulphide material. This resemblance is particularly striking when, as is frequently the case, both have undergone more or less pronounced metamorphism. It is, therefore, not surprising that in the first instance they were confounded and mapped together. Moreover, the presence of the norite as a distinct geological unit was not suspected until long after this first work was completed, the associated greenstones being considered as portions of the norite, which had been metamorphosed by the intrusion of the younger granite masses. Even the Bureau of Mines' map of 1902, which should have furnished the latest information in regard to this area, made no attempt whatever, either to correct the more glaring inaccuracies in the geological boundaries, or to trace out the important line of separation between the nickel bearing eruptive proper and the closely related, though barren greenstones.

The norite a distinct geological unit.

Limit of new work.

In undertaking this new work, it was felt that by confining operations as closely as possible to the area characterized by the presence of the sulphide bearing norite and other kindred eruptives, a more accurate knowledge would be obtained of the mineralogical composition, structure and age relations of the various rock masses, while at the same time the boundaries between the several formations could be drawn with a much greater degree of precision.

Victoria Mines and Sudbury maps.

Two map sheets have been prepared to accompany this report, called respectively the "Victoria Mines" and "Sudbury" maps, each on a scale of one mile to an inch. The former covers an area of 220 and the latter 210 square miles, making a total of 430 square miles. The principal new work on the Victoria mines map has been the outlining of the two smaller bands of norite south of the Canadian Pacific Railway. One of these, crossing the southeast corner of Drury, extends completely across the southern part of the township of Denison. This band, which comes to an end east of the Vermilion river, contains the Worthington, Mitchener and Totten mines. The first mentioned of these mines is famous as having produced the richest nickel ore in the district. On the other band, which forms the prominent ridge to the south of McCharles and Simon lakes on the Whitefish Indian Reserve, no deposit of any economic importance has been found. The boundaries of the intrusive mass of younger granite which extends across the northern and central parts of Graham township, and thence into Snider and Waters townships, have also been outlined with considerable care. It is to be regretted that time did not permit the separation of the norite and the older greenstones and schists, but the geological work done in 1901 was intended to cover the

Minor band of norite.

whole of the southern belt in one season, and at the time it was considered more important to ascertain definitely the continuity or otherwise of the southern or main nickel range. The main mass of the norite, therefore, which runs northeast from the Victoria mines, was followed through the northern part of the township of Denison, and thence across the Vermilion river into the southern part of the township of Creighton, thus making connection with the other mass of similar basic intrusive rocks, which had been shown on geological maps previously issued. With the exception of a somewhat critical examination of some of the outcrops of the peculiar differentiation product, or "micropegmatite" phase of the norite, exposed on the shores of Skill and Fairbank lakes, no new work has been done in the northwestern and western parts of this area, and the outlines of the formations are reproduced from the old geological map.

Revision of geology of Sudbury area.

The geology of the region comprised in the Sudbury map sheet, has all been revised, with special attention to tracing out the boundaries of the various masses of norite and separating this nickel bearing eruptive from the older greenstones. This map will serve to show in a very emphatic manner, the intimate association of this peculiar eruptive, and the various nickel deposits, and the invariable development of the latter along the line of junction between this and the neighboring rocks. In addition to these two map sheets, which exhibit on an adequate scale not only the general geological features, but also the relative position of all the more important mines, there are three other maps, each on a scale of 400 feet to an inch, which may be referred to as mining geological plans. These have been prepared with more care, and all details of topography, buildings, openings, etc., have been laid down as accurately as possible from surveys made by means of the transit and chain. They are expected to be of especial value to the individual companies whose properties they represent, but at the same time, they will illustrate in detail many of the characteristic features of association, which most of these deposits possess in common with one another. The two sheets showing the district in the vicinity of the International Nickel Company's mines at Copper Cliff, and extending from Kelley lake on the south to the Lady Violet mine on the north, cover an area of about 9 square miles. The third map sheet, which shows the geology in the neighbourhood of the Murray and Elsie Mines as well as the position of the various mining buildings, covers an area of nearly two square miles. The following bulletin is based mainly on the field work carried on during the seasons of 1901 and 1902. A short account of what was accomplished each year has already appeared in the Summary Reports of the Geological Survey

Mining geological plans.

Area of Copper Cliff maps.

Murray and Elsie mines map.

Department, (1) In addition to this and other information which has appeared from time to time in the official publications of the Geological Survey Department and the Bureau of Mines of Ontario, certain details of original investigation, which throw much additional light on the origin and association of these deposits, have appeared in various scientific periodicals, many of which are not very easy of access to the ordinary reader. It has been the purpose of the writer, in the preparation of the following report, to bring together and make use of much of this widely scattered information, and by thus supplementing his own, render the present publication of wider application and greater service to the public.

Other information included.

In carrying out the field work, the author was materially aided by Dr. Ludwig Mond of London, England, under an agreement by which he was partially relieved from his duties on the Survey, during the six months from July 1 to December 31, 1901.

Work of Mr. James White.

Much of the accuracy which the accompanying maps are believed to possess, is due to the efforts of Mr. James White, Dominion Geographer, who kindly undertook the direction of the surveys necessary for a detailed mapping on a large scale of the area examined. This included in 1901, a traverse by means of transit and steel band chain, of the main line of theCanadian Pacific Railway, from Wanapitei station to the northern boundary of the township of Dowling, a short distance northwest of Onaping station. The "Sault" branch was similarly surveyed from Sudbury Junction as far west as Worthington station. Connection was made with the observatory at Rayside, occupied by Astronomer O. J. Klotz. The position of this temporary observatory, in the township of Rayside is stated by Mr. Klotz to be 606 feet west of the line between lots 2 and 3, in con. 1, and 441 feet north of the centre line of the Canadian Pacific Railway. Its astronomical position, as determined by Mr. Klotz is Long. 81°, 05′, 38″ W. and Lat. 46°, 32′, 47″ N. This position was accepted and the projection of the map framed in accordance therewith. In 1902, Mr. White carried on similar detailed surveying necessary for the preparation of the two large scale map sheets of the area in the vicinity of the International Nickel Company's mines at Copper Cliff.

Work by Ast. O. J. Klotz.

Work by O. E. Leroy.

In the whole of this work, the author had the advantage of the zealous and able assistance of Mr. O. E. Leroy, M. A. Sc., formerly Demonstrator in Geology at McGill University, Montreal, and this opportunity is taken to express his keen appreciation of Mr. Leroy's untiring efforts to promote in every way, the objects of the work.

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(1) Sum. Rep. Geol. Sur. Can. (1901) pp. 141-145, (1902) pp. 252-267.

Work by W. M. Ogilvie.

By kind permission of Dr. J. B. Porter, and with the approval of the University authorities, the magnetic separation of these ores was carried on in the mining laboratories of McGill University by Mr. W. M. Ogilvie, B.A. Sc.

Work by Donald Locke.

Most of the assays and analyses are the work of Mr. Donald Locke, a graduate of the School of Mines, Freiberg, Germany, who for a short time was attached to this department as metallurgist and assayer.

Acknowledgments.

The author desires to express thanks for information and assistance to Dr. Ludwig Mond, Dr. Bernhard Mohr and other officials of the Mond Nickel Company; to President A. P. Turner, Captain Lawson and other officers of the International Nickel Company, resident at Copper Cliff, Ont.; to the representatives of the Lake Superior Power Company, Great Lakes Copper Company and H. H. Vivian and Company, who were stationed in the district. It would be difficult to mention by name, all those who, either with information or otherwise, have assisted in the object of these investigations, but the author would like in this connection to express his deep gratitude to the residents of Sudbury, Copper Cliff and Victoria Mines, who showed him the greatest kindness and consideration during his sojourn in their midst.

PREVIOUS EXAMINATIONS AND DESCRIPTIONS.

Deposits of scientific and economic interest.

The literature in regard to the nickel and copper deposits of the Sudbury mining district, has already reached such large proportions, that it seems advisable in passing to make brief mention of some of the principal publications, which show evidence of original research, the results of which have added materially to our knowledge of the nature of the occurrences of these immense ore bodies. These deposits of pyrrhotite, with their unusually high content of nickel, and intimately associated chalcopyrite, are of importance, not only from the economic standpoint, but also from the point of view of science, as having furnished such strong presumptive evidence for regarding these, and similarly related deposits as of igneous origin, aud due to processes of differentiation in the original magma, from which they and the associated eruptive rocks have solidified.

Discovery of nickel at Wallace mine.

The discovery of nickel at the Wallace mine in 1846, (1) although creating some excitement at the time, was soon forgotten, as well as the prediction which has since been amply verified, that deposits of both nickel and cobalt of economic importance would yet be located in this region. Attention was again drawn to the subject by the finding in 1856 (¹) of nickel and copper on Salter's meridian line, a little over six miles north of Whitefish lake, and less than half a mile southwest of the main pit of the present celebrated Creighton mine, probably the largest deposit of nickeliferous pyrrhotite in the world. This was again lost sight of or the discovery considered of no importance, perhaps because of the meagre information in regard to its occurrence, but more likely on account of the wild and inaccessible nature of the district, in which the deposit had been found. The opening of the Canadian Pacific Railway quickly changed these conditions, and in less than ten years from the first opening of this means of access to the district, all the mines which are at present working had been located.

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(1) Rep. of. Progress, Geol. Sur. Can., 1848-49, pp. 61-63; Geol. of Can. 1863, p. 506.

Early discovery of nickel near Creighton mine.

Inaccessible nature of country before constructon of C. P. Ry.

First statistics.

The first statistics concerning these deposits which were published, related to the export of copper ore in 1886, amounting to 3,307 tons, with a declared customs value of $16, 404 (²). In 1887, this quantity had decreased to 567 tons, valued at $3,416 (³). The discovery of nickel in the ore about this time, decided the Canadian Copper Company to instal the necessary plant for the production of nickel and copper matte, and in the preparation for this and other mining development work, no exports are recorded from this district in 1888.

Descriptions by J. H. Collins.

In October, 1887, Mr. J. H. Collins visited the Sudbury region to examine into the extent and economic possibilities of the so-called copper mines. On June 6th, 1888, he read a paper before the Geological Society of London, 'On the Sudbury Copper Deposits,' in which he embodied the results of these examinations, which, however, seem to have been restricted mainly to the area in the immediate vicinity of the Copper Cliff and Stobie mines. An abstract of this paper, was afterwards published,(⁴) accompanied by two cross sections of the mines above mentioned, showing the geological association and position of these deposits. The author considers the main ore bodies to have been the result of secondary action, the sulphides occupying fissures along certain lines of weakness, produced by the intrusion of igneous material. In the discussion that followed, Mr. Attwood stated his conviction that the diorites had brought up the metals. At the end of the paper, a note is added bearing the date of October 22nd 1888, that the ore of the Evans mine contains Copper 3%, Nickel 3.5%, Iron 40%, Sulphur 24%, Rock 29.5 %.

Mr. Attwood's opinion.

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(1) Rep. of Progress, Geol. Sur. Can., 1853-56, pp. 180-181.

(2) Ann. Rep. Geo. Sur. Can. 1886, Part S. p. 25.

(3) " " " " " 1887-88, Part S, p. 21.

(4) Quart. Jour. Geol. Soc. Lon., Vol. XLIV, 1888, pp. 834-838.

Discovery of sperrylite by F. L. Sperry.

In October, 1888, Mr. Francis L. Sperry, then chemist to the Canadian Copper Company, sent a small quantity of what seemed a remarkable mineral to Professor H. L. Wells, of the Sheffield Scientific School at New Haven, Conn. A few tests sufficed to show that the substance was essentially an arsenide of platinum. Several ounces of this mineral had been obtained in milling certain loose material (gossan), associated with the sulphides at the Vermilion mine in the township of Denison. A complete statement of facts relative to its composition, physical characters and crystallographic behaviour, was prepared by Profs. Wells and Penfield, who proposed the name 'sperrylite' for this new mineral in honour of its discoverer. (1)

Description of mineral by Profs. Wells and Penfield.

Discovery of polydymite by Profs. Clarke and Catlett.

About the same time, Profs. Clarke and Catlett (2) of Washington, obtained through two different channels, certain samples of nickel ores taken from the Vermilion mine, belonging to the Canadian Copper Company. From one source, they obtained two masses of sulphides to be examined for nickel and copper, from the other came similar sulphides, together with a series of soil and gravel-like material (gossan), seven samples in all. In the latter case, an examination for platinum was requested, and in five of the samples above mentioned, it was found the gravel yielded 74·85 ozs. of metals of the platinum group to the ton of 2,000 lbs. The sulphide ores were all of a similar character. They consisted of mixed masses, in which a gray, readily tarnishing substance was predominant, with some chalcopyrite, possibly some pyrite, and a very little quartz. An analysis of carefully selected material of the nickel mineral, showed its formula to conform in general with that of polydymite, which had previously been described by Laspeyres from Grünau, Westphalia, of which it is evidently a ferriferous variety.

Paper by W. H. Merritt.

At the Buffalo meeting of the American Institute of Mining Engineers, W. H. Merritt, Toronto, contributed a paper on 'The Minerals of Ontario and their Development', in which he includes a brief description of the Sudbury deposits. (3)

Examinations and descriptions by Dr. Bell in 1888.

In the Summary Report of the Geological Survey for 1888, Dr. Bell (4) mentions that 'the modes of occurrence and the geological relations of the economic minerals of the districts examined (between Lake Huron and Montreal river) were carefully studied. The metals which give most promise are the copper and nickel deposits which have been worked for the last three years near Sudbury'. Again, in the report for 1889, Dr. Bell, (¹) after a brief sketch of the geology of the area included in the Sudbury map sheet, gives a few notes on the character and mode of occurrence of these deposits, as also the progress of the mining and metallurgy which were then in vigorous operation. He viewed the pyrrhotite a sa true nickeliferous variety, in which some of the iron is replaced by nickel. The deposits are described as 'stockworks' in which the vein structure is very obscure. The ore bodies are regarded as usually occurring in some form of diorite, the concentration of the ore being perhaps connected in some way with certain diabase dykes which were in some cases seen near the deposits.

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(1) Amer. Jour. Sc., Vol. XXXVII, 1889, pp. 67-73; also Zeit. für Kryst. Vol. XV, pp. 285 and 290-291.

(2) Amer. Jour. Sc. Vol. XXXVII, 1889, pp. 372-374.

(3) Trans. Amer. Inst. Min. Eng., Vol. XVII, 1888-89, pp. 293-300.

(4) Ann. Rep. Geol. Sur. Can. 1887-88, p. 79 A.

Account by Dr. E. D. Peters.

At the Ottawa meeting of the American Institute of Mining Engineers, held in October, 1889, Dr. E. D. Peters, who had charge of the operations at the Canadian Copper Company's mines near Sudbury, read a paper 'On the Sudbury Ore Deposits'. (²) He opens with a short and very general statement of the geological conditions, makes a passing mention of the two principal sulphides which constitute these deposits, and devotes the rest of his paper to a description of the equipment and methods of mining and metallurgy pursued by the company of which he was the manager.

Reference by Dr. Bell in 1890.

In 1890, as one of the Royal Commissioners to inquire into the mineral resources of Ontario, Dr. Robert Bell of the Geological Survey of Canada, in the treating of the "Geology of Ontario with special reference to economic minerals," devotes some attention to the nickel and copper deposits of the area in the vicinity of Sudbury. (³)

Report by Dr. Bell in 1891 on 'Sudbury Mining District.'

In 1891 (⁴), Dr. Bell described in greater detail the nature and extent of these deposits and also their geological relations, giving the results of the field work of the Geological Survey in this area during the three years 1888-90. Accompaying the same volume, the first geological map of the district appeared, showing in this graphic way, the limits of the different formations or subdivisions of these old rocks, over an area of 3456 square miles. This map, although faulty and inaccurate in places, has been the basis of all subsequent geological work undertaken in this district, although it is now superseded in

First geological map.

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(1) Ann. Rep. Geol. Surv. Can. 1888-89, pp. 29-32 A.

(2) Trans. Am. Inst. Min. Eng., Vol. XVIII (1889) pp. 278-289.

(3) Min. Res. of Ont. 1890, p. 24; also pp. 433-435, also Ann. Rep. Bur. of Mines, Ont. 1891, pp. 88-90.

(4) Ann. Rep. Geol. Sur. Can., Vol. V, 1890-91, Part F, pp. 1-95; also Bull. Geo. Soc. Am., Vol. II, 1891, pp. 125-137.

certain areas, by the maps lately published by the Bureau of Mines of Ontario, and those issued to accompany the present bulletin. The imperfections of these latest maps will also in turn become apparent as the region is cleared and opened up and more detailed information in regard to the distribution of the various rock masses is thus possible.

Description by A. E. Barlow.

On March 6th, 1891, (1) the author of the present bulletin read a paper before the Logan Club of Ottawa 'On the Nickel and Copper Deposits of Sudbury,' which was published in June of the same year, in which appears a very definite statement affirming an igneous origin (2) for these masses of sulphide material, in the following words :

Origin of ore-bodies.

Nickel does not replace iron.

First recognition of pentlandite.

'The ores and the associated diabase, were, therefore, in all probability simultaneously introduced in a molten condition, the particles of pyritous matter aggregating themselves together in obedience to the law of mutual attraction.' In the same paper, the author makes the following significant statement which has since been proved by means of the magnetic separation of the ore: 'The nickel is usually spoken of as replacing an equal quantity of iron in the pyrrhotite, but the discovery of undoubted crystals of millerite or sulphide of nickel, 150 feet below the surface at Copper Cliff mine, as well as the more recent recognition of polydymite, a ferriferous sulphide of nickel at the Vermilion mine, in the township of Denison, seem to justify the assumption that in the more highly nickeliferous deposits of the region at least, the nickel is also present as a sulphide, disseminated through the ore masses like the iron and copper.' In 1891, Mr. T. L. Walker, then chemist at the Murray mine, obtained 30 per cent of nickel in some bright cleavable fragments of a mineral which occurred in the form of more or less rounded patches in the ordinary nickeliferous pyrrhotite at the Worthington mine. The writer, who had provided Mr. Walker with these samples, suggested the advisability of a complete analysis of as pure material as could be selected. It is to be regretted for Walker's sake, so far as priority in the first recognition of pentlandite in this district is concerned, that the present writer, in publishing the results of this first analysis (3), merely stated his own belief, that these peculiar nodular masses probably represented a mixture in which millerite was the most prominent constituent, omitting to make mention of the fact that, the chemist had stated his belief, that the material was almost pure "Eisennickelkies" the German synonym for pentlandite. At this time, it was considered of more importance to emphazise the fact which had grown beyond a conviction, that the nickel was undoubtedly present in these ore bodies as a distinct sulphide, mechanically intermixed and probably separable and not as replacing a portion of the iron in the pyrrhotite. It was even considered probable that several nickel sulphides, and not one alone, contributed to the unusual enrichment of these ores.

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(1) Ottawa Naturalist, June 1891, pp. 1-20 ; also Ann. Rep. Geol. Sur. Can., Vol. V, Part S, 1890-91, pp. 122-138.

(2) See also a paper by Dr. Robert Bell on 'The Nickel and Copper Deposits of Sudbury District, Canada.' Bull. Geol. Socy. of Am., Vol. II, 1891. page 135-36.

(3) Ann. Rep. Geol. Sur. Can. 1890-91, Part SS, pp. 116-117.

First detailed statistics of nickel.

The report of the Division of Mineral Statistics and Mines of the Geological Survey for 1890, although not published until the following year, contained the first statistics showing the production and export of nickel and copper matte from the Sudbury district. This was likewise accompanied by a somewhat detailed description of the deposits, to which attention has already been drawn (1). Previous to this, however, in the report (2) of the same department for 1889, mention is made of the production of nickel in Canada, but the figures of production then supplied were only used in the summary of production. This course was necessary at the time, as the figures then available represented the production of only one company, who gave the figures on the understanding that they were only to be used in the compilation of totals.

Descriptions by Bureau of Mines of Ontario in 1891.

In the first report of the Ontario Bureau of Mines for 1891, then just organized, considerable space is devoted not only to the statistics of production of nickel and copper matte, but also to various details regarding the geological relationship of the ores, the methods of mining and metallurgy, as well as the use and value of nickel. It also contains the first of the annual reports of the inspector of mines, which each year since has contained an epitomized statement of the progress of mining and smelting in this area.

Paper by J. Garnier.

In 1891, Mons. J. Garnier, (3) who had become famous as the discoverer of the New Caledonia nickel deposits, visited Canada, and on his return to Paris, furnished an account of his examination in a paper entitled, 'Mines de Nickel, Cuivre et Platine du District de Sudbury, Canada.

Analyses and magnetic separation of Sudbury ores by Dr. Emmens.

In 1892, Dr. S. H. Emmens of Youngwood, Penn., and President' of the Emmens Metal Company, announced the discovery of three new nickel minerals from the Sudbury district, for which he proposed the names Folgerite, Blueite and Whartonite. (4) The substances thus named, were stated to be sulphides of iron and nickel, the proportion of the latter metal varying from 3·76 per cent in blueite to 35·20 per cent in folgerite. All authorities are, however, agreed that none of these are definite mineral species, being mixtures of different sulphides. Thus folgerite is regarded as impure pentlandite, blueite is a nickeliferous pyrite, and whartonite a mixture. A persual of Dr. Emmens' methods of analysis, and the variability of his results are sufficient proofs, that none of these names which he proposes, should receive a place in mineralogical literature. About the same time, Dr. Emmens conducted some rather crude and evidently hurried experiments in regard to the separation of the components of the pyrrhotite by means of magnetism, but the results are far from satisfactory. (¹) The material on which the trials were made came from both the Gap mine, Pa., and Sudbury, Ont.

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(1) Ann. Rep. Geol. Surv. Can., 1890-91, Part. S, pp. 121-143.

(2) Ann. Rep. Geol. Surv. Can., 1888-89, Part. S, 1889, pp. 5 and 123.

(3) Mem. Soc. des Ing. Civils, Paris, 1891.

(4) Jour. Am. Chem. Soc., Vol. XIV, No. 7; also Ann. Rep. Bur. of Mines, Ont., 1892, pp. 167-170.

Folgerite whartonite and blueite not true mineral species.

In 1892 Mons. David Levat, formerly Director-General of the Société le Nickel, prepared a memoir on the production and uses of nickel and its alloys, entitled 'Progrès de la Métallurgie du Nickel,' (²) an abstract from which is translated and printed in the report of the Bureau of Mines of Ontario. (³) Besides a description of the metallurgical treatment of the Sudbury ores, he institutes a comparison between these and the New Caledonia ores, giving all necessary details in regard to these latter, their composition, metallurgy, transportation, mining operations, and concludes with certain particulars relating to the composition of the nickel of commerce, its alloys and statistics of production.

Memoir on nickel by Mons. David Levat.

During the summer of 1890, the late Baron von Foullon of the Geological Survey of Austria, spent a few weeks in the district, directing his attention chiefly to the determination of the relative ages of the different rocks. His collection of rocks for future study, contained a specimen obtained from one of the detached blocks of material, which had been blasted out to make room for the the foundations of the smelter at the Murray mines. Examination of thin sections of this specimen under the microscope, revealed for the first time the identity of what was evidently a typical and unaltered representative of the nickel bearing eruptive, showing it to contain besides the plagioclase, strongly pleochroic hypidiomorphic individuals of hypersthene, together with a smaller amount of diallage, both these last mentioned minerals being often bordered with hornblende. The rock thus evidently belonged to the general type of gabbros, which by the abundance of the hypers-

Work by Baron von Foullon.

First recognition of nickel bearing eruptive.

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(1) Jour. Am. Chem. Soc., Vol. XIV, No. 10; also Ann. Rep. Bur. of Mines, Ont., 1892, pp. 163-166.

(2) Ann. des Mines, Paris, 1892, pp. 141-224.

(3) Ann. Rep. Bur. of Mines, Ont., 1892, pp. 149-162.

Description of gabbro by G. H. Williams.

thene is related to the norites. (1) This was the first recognition of the true character of the eruptive with which the nickel deposits are so intimately associated, although the late Professor G. H. Williams had in 1891 described (2) a very similar rock from the vicinity of the Blezard mine, but which in the description of the field relations furnished him, had been reported as occurring in a later dyke. In 1893, Dr. A. P. Coleman,(3) showed that the country rock of the nickel deposits south of Clear Lake, on the Northern Nickel Range, was a gabbro containing both diallage and enstatite. In the same publication, he gives a description of the petrographical characters of the peculiar type of rock to which Williams first gave the name "micropegmatite," and which occurs here as elsewhere, throughout the district, in intimate association with the sulphide bearing eruptive.

Coleman's description of norite and related rocks from North Nickel Range.

Recognition of pentlandite by Prof. Penfield.

In 1893, Prof. S. L. Penfield, recognized and described for the first time, the mineral pentlandite, from the Sudbury district, found in some sulphide material sent to him some years previously by Mr. F. L. Sperry. (4) Immediately following this article, in the same publication, he criticizes rather severely the methods of analysis, adopted by Dr. Emmens, in his attempt to establish the claims of folgerite, blueite and whartonite, to be recognized as new mineral species (5).

Magnetic separation by David H. Browne.

In the same year David H. Browne, (6) chemist of the Canadian Copper Company, challenged the accuracy of Dr. Emmens' magnetic work, as also the conclusions based thereon, so far at least as the material from Sudbury is concerned. At the same time, he published the details of certain personal experiments in connection with the magnetic separation of the ores from the Copper Cliff, Evans and Stobie mines. The ore was first handpicked and then crushed to various degrees of fineness. By means of these trials, he succeeded in dividing the material thus prepared into a magnetic and non-magnetic product, the analysis of the latter showing a close resemblance to the pentlandite described by Penfield.

Examination of sperrylite. by T. L. Walker.

In June 1893, T. L. Walker (7) visited the Vermilion mine and procured some additional material similar to that in which Wells and

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(1) "Ueber einige Nickelerzvorkommen," Jahr. d. k-k. geol. Reichsanstalt, Vol. XLII, pp. 223-310, Vienna, 1892.

(2) Ann. Rep. Geol. Surv. Can., 1890-91, Part F, p. 77.

(3) "The Rocks of Clear Lake near Sudbury," Can. Rec. Sc., Vol. V, 1892-93, pp. 343-346.

(4) Am. Jour. Sc., Vol. XLV, 1893, pp. 493-494.

(5) " " " pp. 494-497.

(6) Eng. & Min. Jour., Dec. 2nd, 1893, Vol. LVI, pp. 565-566.

(7) Am. Jour. Sc., Vol. I, 1896, pp. 110-112.

Penfield had first discovered sperrylite. The evidence of these new specimens of this comparatively rare mineral, enabled him to publish further details in regard to its crystallographic behaviour. After critical examination of the associated sulphides, he concludes that this sperrylite is associated with the chalcopyrite, and not with the pyrrhotite, and that accordingly nickel mattes from mines low in copper contain very little platinum, while those richer in copper afford a matte proportionately richer in platinum. He mentions the fact, however, that the polydymite of Clarke and Catlett contains from 0·006 per cent to 0·024 per cent of platinum (1).

Discovery of nickeliferous pyrite by Prof. W. L. Goodwin and T. L. Walke

In April, 1893, Prof. W. L. Goodwin (2) announced the discovery of a highly nickeliferous pyrite, occurring at the Murray mine, and published an analysis of this somewhat unusual association. The material, however, on which the examination was conducted, was massive and somewhat decomposed. A little latter, however, T. L. Walker secured several specimens showing druses of small bright cubic crystals. These were found associated with marcasite, (containing no nickel or cobalt) magnetite, galena, chalcopyrite and nickeliferous pyrrhotite. An analysis of this new and fresh material was made, and the conclusion reached that the specimens represented true nickeliferous pyrite. in which the isomorphus elements, iron and nickel, replaced each other in varying proportions. (3)

Description by E. Renshaw Bush.

During the summer and fall of 1893, E. Renshaw Bush, while pursuing professional work, visited some of the more important deposits, afterwards publishing his observations in a paper called 'The Sudbury Nickel Region.' (4)

Paper by Philip Argall.

On December 4th, 1893, Philip Argall of Denver, Col., presented a paper to the Colorado Scientific Society, on 'Nickel, the Occurrence, Geological Distribution and Genesis of its Ore Deposits.' This author gives a short but rather complete statement of the character, composition and distribution of the three groups of the ores of nickel—arsenides, sulphides and silicates—and makes special mention of the main features and importance of the Sudbury Ore Deposits.(5)

Opinions by Dr. F. D. Adams.

On January 12th, 1894, Dr. Frank D. Adams of Montreal, submitted a paper to the General Mining Association of the Province of

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(1) Bull. U. S. G. S., No. 64, p. 21.

(2.) Can. Rec. Sc. Vol. V, 1892-93, pp. 346-347.

(3.) Am. Jour. Sc. Vol. XLVII, April, 1894, pp. 312-314.

(4.) Eng. & Min. Jour., March 17, 1894, Vol. LVII, pp. 245-246.

(5.) Proc. Col. Sc. Soc., Vol. IV, 1891-92-93, pp. 395-421.

Quebec, 'On the Igneous Origin of certain Ore Deposits.' In this paper, he gives a synopsis of the main conclusions reached by Prof. J. H. L. Vogt of Christiania, from his examinations and study of the nickeliferous sulphides of Norway, and agreeably with these, Dr. Adams claims an igneous origin for the various Sudbury occurrences, the concentration of the ore being the direct result of magmatic differentiation of the peculiar type of eruptive with which the deposits of both countries are always associated. (1)

Views by Prof. J. F. Kemp.

In 1895, Prof. J. F. Kemp of Columbia University, New York, gives 'An Outline of the Views held today on the Origin of Ores' offering an explanation, based on the laws of thermo-chemistry, to explain the concentration of these sulphides of iron, copper and nickel. (2)

Detailed description by Dr. T. L. Walker.

In 1897, Dr. T. L. Walker presented his inaugural dissertation to obtain the degree of Doctor of Philosophy, to the University of Leipzig, taking as his subject 'Geological and Petrographical Studies of the Sudbury Nickel District, Canada.' This thesis was afterwards communicated to the Geological Society of London, by Prof. J. J. H. Teall and subsequently published in an abridged form. (3) This publication contains an epitome of Dr. Walker's studies of the rocks which are most intimately associated with the nickel deposits. The author is in full agreement with Vogt, Adams and others, regarding these ore bodies as of igneous origin, owing their present position and dimensions to magmatic differentiation. He furnishes very complete details of the petrographical character, not only of the nickel bearing eruptive, but also of the associated greenstones and the clastic rocks of the Huronian, making brief mention of the mineralogical composition of the Laurentian gneisses exposed near Wanapitei station. Dr. Walker was the first to recognize that the 'micropegmatite', classed on previous geological maps, as belonging to the Laurentian, which it resembles, is really a differentiation phase of the prevailing norite. The later dykes of olivine diabase are also described in considerable detail. The whole publication may be characterized, in brief, as the most complete statement in regard to the geology and petrography of the district, which had yet appeared.

Dr. Walker first to recognize the micropegmatite as differentiate of norite.

Paper by J. W. Bain.

In 1900, J. Watson Bain prepared 'A Sketch of the Nickel Industry,' which treats of the source and production of nickel ores, the me-

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(1.) Can. Min. Review, February, 1894.

(2.) Min. Industry, Vol. IV, 1895, pp. 755-766.

(3) Quart. Jour. Geol. Soc. Lon., Vol. LVIII, (1897) pp. 40-66.

tallurgy of both the New Caledonia and Sudbury products, concluding with a brief statement of the composition and uses of nickel. (1)

Description by Dr. Coleman in 1901.

In 1901, Dr. A. P. Coleman gives certain petrographical details of the nickel bearing eruptive and the associated greenstones, with special reference to occurrences of these rocks, between the Stobie and Nickel Mountain mines. He also furnishes an account of the mineralogical composition and character, as revealed by the microscope, of some of the sedimentary rocks classified as Huronian in this district. (2)

Work by A. E. Barlow in 1901 and 1902.

In 1901, (3) and again in 1902, (4) the writer gives certain preliminary information in regard to the geology and petrography of the Sudbury district.

Sperrylite by Goldschmidt and Nicol.

In the summer of 1902, Profs. Victor Goldschmidt and William Nicol prepared a very complete statement of the crystallography of sperrylite, the material being obtained from the original locality at the Vermilion mine. (5)

Separation of sperrylite from chalcopyrite by Dickson.

In 1902, C. W. Dickson, (1851 Exhibition Scholar from Queen's University, Kingston, and doing post-graduate work at the School of Mines, Columbia University, New York) succeeded in separating sperrylite from the unaltered chalcopyrite, obtained at the Victoria mines, and thus proved definitely that the platinum was associated with the copper sulphide. (6) This is in agreement with the results obtained by Walker, some years previously, to which reference has already been made, and also accords with the views of Prof. Vogt, from analyses of the various ores from the Norwegian nickeliferous pyrrhotite deposits. (7)

Paper by C. W. Dickson.

At the meeting of the American Institute of Mining Engineers, held in Albany in February, 1903, Mr. Chas. W. Dickson, to whom reference has already been made, submitted a paper entitled 'The Ore Deposits of Sudbury, Ontario.' The information thus published was also presented in the form of a thesis ,to obtain the degree of Ph. D. at Columbia University, New York city. (8)

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(1) Ann. Rep. Bur. of Mines, Ont., 1900, pp. 213-224.

(2) Ann. Rep. Bur. of Mines, Ont., 1901, pp. 206-208.

(3) Sum. Rep. Geol. Surv. Can., 1901, pp. 141-145.

(4) " " " 1902, pp. 252-267.

(5) Amer. Jour. Sc., Vol. XV, 1903, pp. 450-458.

(6) " " " " 137-139.

(7) Zeit für Prak. Geol. Aug., 1903, pp. 258-260.

(8) Trans. Am. Inst. Min. Eng. (Albany Melting) February, 1903, 65 pp.

New methods of research.

This publication marks a decidedly new departure, not only in the methods of research adopted, but also in the results sought to be obtained, and if the conclusions reached, seem new and startling, and at variance with many of the preconceived notions entertained in regard to the composition and origin of these ore bodies, the author must be given the credit for having weighed all the evidence and exhausted every means to prove the validity of his conclusions.

Mr. Dickson mentions that one of the purposes of his investigation has been to ascertain whether the nickel and cobalt replace the iron isomorphously in the Sudbury pyrrhotite. Another purpose has been to try to find a definite formula for the sulphide of this district, with the idea of comparing it with similar minerals from other localities. The thesis is divided into two main portions, as follows: I. The relation of nickel to pyrrhotite and II. Genesis of the Sudbury ores.

Analyses of Sudbury ores & pyrrhotites.

The first of these two parts of Mr. Dickson's paper deals, in the first place, with a general statement of the Sudbury nickel region. This is followed by a summary of the composition and origin of pyrrhotite, to which is added a table, showing the percentage of nickel and cobalt, in this mineral. Then succeeds a brief description of the Sudbury pyrrhotites, with tables indicating the percentages of nickel, cobalt and copper, not only in the ore of the principal mines, but also the average composition of some of the resulting mattes.

Magnetic separation of pyrrhotite.

Mr. Dickson then discusses the methods pursued, and the results of his investigation into the magnetic separation of the pyrrhotite, and as a result of these experiments, he concludes that all of the nickel, in the Sudbury ores at least, occurs as a separate mineral, and, that in this district there does not exist a true nickeliferous pyrrhotite, in the sense that the nickel isomorphously replaces part of the iron in that mineral.

Nickel does not replace iron in pyrrhotite.

In the second part of the paper, he adduces strong evidence in support of his opinion that all of the Sudbury ore deposits are of essentially and predominantly secondary origin. The evidence adduced, is derived not only from a study of the larger field occurrences of the deposits and associated rocks, but also finds abundant support in the relations between the ores and rock minerals, as seen under the microscope.

Comparisons.

A comparison is made of these Sudbury deposits with those of Rossland, B. C., and Ducktown, Tenn., which are stated to show many remarkable and essential points of similarity, and concerning whose secondary origin, there can be no doubt.

Dr. Coleman's examinations and descriptions in 1903.

In 1903, Dr. A. P. Coleman published his account of 'The Sudbury Nickel Deposits', (¹) giving the results of the field operations under-

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(1) Ann. Rep. Bur. of Mines, Ont., 1903, pp. 235-299.

taken at the instance of the Bureau of Mines of Ontario, in the summer of 1902. This is, doubtless, the most comprehensive and satisfactory description of these deposits which has yet appeared. This work is copiously illustrated with photographs of the different mines and buildings, together with several small maps showing the progress of the surface work, and the disposition of the various openings and mining buildings. It is also accompanied by two coloured geological maps, representative of the area in the vicinity of the Copper Cliff and Stobie mines. It is not considered necessary in this connection, to summarize the results of this work, as the publication is of such recent date, and readily available to any one who desires to take advantage of this information; and no one interested in the geological and petrographical problems involved, should be without it. In 1903, Dr. Coleman continued this work, directing his attention to the mapping out in detail of the outline of the northern nickel range, in order to determine its connection or otherwise with the Southern or Main Range.

Geological maps of Copper Cliff and Stobie mines.

It is proposed, that during the coming season, Dr. Coleman will again continue this work, with the intention of ultimately publishing a monograph, which will contain, in succinct form, all essential information in regard to these deposits, which have figured so largely in the mining industrial development of Canada.

Further detailed work by Dr. Coleman.

HISTORY OF DEVELOPMENT.

The presence of large deposits of nickel and copper, in the vicinity of the town of Sudbury, and close to the boundary between the Districts of Algoma and Nipissing, in Northern Ontario, has, for many years, attracted world wide attention, in the first place, on account of their immense and apparently inexhaustible character, but latterly, because of the much more extended use of nickel, especially as an alloy with steel, to improve the qualities of the latter. The recent agitation for the imposition of an export duty on nickel ore and matte, has, at least, resulted in drawing public attention to the fact, that Canada has for some time past, been one of the two great sources of nickel in the world, and at the present day, produces more than half of the world's consumption of this metal. The history of the development of nickel mining in this region is inseparably bound up with that of copper, for the two minerals are always present in such intimate association with one another, that, in abstracting their metallic contents, they are subjected to the same metallurgical processes.

Public attention attracted to these nickel and copper deposits.

Knowledge of existence of copper in 1770.

The existence of workable deposits of copper in this region, was a fact that had long been known, and as far back as 1770, a company had been formed and attempts made to mine this metal, but the difficulty of procuring and maintaining miners, at so great a distance from any centre of civilization, the remoteness of any market for the ore, as well as the absence of facilities for transportation, were in themselves amply sufficient causes, if none other existed, to render these first attempts abortive. However, in 1846, owing to the activity in prospecting and locating mineral lands, on the southern shore of Lake Superior, and a favourable report by Mr. W. E. Logan, then newly appointed Provincial Geologist, some enterprising Canadians banded themselves together into two associations called 'The Montreal Mining Company', and 'The Upper Canada Mining Company.' The former company purchased, amongst others, what was then known as 'The Bruce Mines Location', and, on account of the apparent richness of the deposit, decided to commence active work at this locality, while the Upper Canada Company proceeded to develop and work what was known as the 'Wallace Mine', near the mouth of the Whitefish river, on Lake Huron. The Wallace mine was the choice of a number of locations, owned by the same company, on the north shore of Lake Huron, and was selected on account of its promising character and proximity to civilization. It is chiefly remarkable as having been the first place in Canada, in which the presence of nickel was detected. After sinking a shaft to the depth of between 60 and 90 feet, and the opening up of a few pits to test the size of the deposit, all work was abandoned, and has not been resumed since, as the quantity of ore encountered in these operations did not seem to warrant any further expenditure.

Work started at Bruce Mines.

Mining work at Wallace mine.

Murray's description of southwestern extension of Creighton mine in 1856.

In his report for 1856, Mr. Alex. Murray,(1) thus refers to certain outcrops of sulphide bearing rocks, which were long afterwards shown to be the southwestern extension of the now famous Creighton Nickel mine. 'At the fifth mile a dingy green magnetic trap, with a large amount of iron pyrites, forms a ridge, and that rock with syenite, continues in a succession of ridges to the seventh mile, beyond which the country becomes low and marshy. Previous to my visit to Whitefish lake, I had been informed by Mr. Salter that local attraction of the magnet had been observed by himself, while he was engaged in running the meridian line, and he expressed it to be his opinion that the presence of a large body of iron ore was the immediate cause. When, therefore, I came to the part indicated by Mr. Salter, I made a very careful examination, not only in the direction of the meridian line, but for a considerable distance on each side of it, and the result of my examination was that the local attraction, which I found exactly as described by Mr. Salter, was owing to the presence of an immense mass of magnetic trap.

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(1) Rep. Geol. Surv. Can. 1853-56, pp. 180-181.

Variation of compass and supposed cause.

The compass was found while traversing these trap ridges, to be deflected from its true bearing upwards of ten degrees at several parts, and in one place it showed a variation of fifteen degrees west of the true meridian, or about twelve degrees from the true magnetic north. Specimens of this trap have been given to Mr. Hunt for analysis, and the result of his investigations shows that it contains magnetic iron ore and magnetic iron pyrites, generally disseminated through the rock, the former in very small grains; titaniferous iron was found in association with the magnetic ore, and a small quantity of nickel and copper with the pyrites. It was remarked that notwithstanding the powerful influence of this magnetic mass in causing a general local attraction, the contact of fragments of it with the compass, although producing a slight effect, rarely occasioned any remarkable agitation of the needle.'

Position of deposit.

The line referred to in the above description, was what was once known as 'Salter's Meridian line', and the exact position of these outcrops of mineralized 'trap', on the line, is in the first concession, on the boundary between Snider and Creighton townships. It can thus be seen, that even at this early period of its history, the officers of the Geological Survey were aware of the existence of nickel in this region, and had pointed out the probability, that workable deposits would be found. ([1])

Inaccessible nature of country before passage of C. P. Ry.

Years passed by, and the inaccessible nature of the country deterred prospectors from making any very detailed exploration or examination, so that it was not until 1883, when the Canadian Pacific Railway was in course of construction, that the first discoveries of any consequence were made, since which time, the whole belt characterized by the presence of the Huronian rocks in the Sudbury district, has been overrun with eager prospectors and miners.

Discovery of Murray, mine by Dr. Howey.

A not infrequent accident in newly settled districts, led to the first important discovery. Judge McNaughton, late Stipendiary Magistrate at Sudbury, had been lost in the woods to the west of the town, and a diligent search was at once instituted for him. A party, consisting of Dr. Howey and two others, found the judge seated on the

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(1.) Rep. Geo. Sur. Can. 1848-49, p. 63.

small eminence which then marked the site of what is now known as the Murray mine. Dr. Howey's natural curiosity and geological turn of mind are well known to all his friends, and it is not surprising, therefore, that having overcome his anxiety on the Judge's account, he should turn his attention to the neighbouring rocks. Looking down at the knoll, which had served as a resting place for the tired wanderer, he noticed that the rock composing it contained abundant impregnations of what appeared to be a valuable ore of copper. More critical examination still, convinced him, that he had discovered a mine and hastily securing some representative samples, he exhibited them to Drs. Girdwood and Selwyn, who happened to be in the neighbourhood, and either of whom he considered fully competent to pronounce with authority as to the economic value or possibilities of his find. Dr. Girdwood, it may be remarked, was, at the time, one of the chief medical advisers of the Canadian Pacific Railway, and a well known authority on chemistry and mineralogy. Dr. Selwyn, then Director of the Geological Survey, accompanied Dr. Girdwood, in order to obtain the necessary transportation facilities, enabling him to make a geological reconnaissance of the area in the vicinity of the railway. To Dr. Howey's surprise, they informed him that the pyrrhotite which formed such a large proportion of his samples, was practically valueless, that the only metal of importance which might be present in such a mineral was nickel, and that past experience with similar ores in Canada and elsewhere, had taught them, that this was always present in such small amount as not to permit of its profitable extraction. Turning their attention to the chalcopyrite, which was also represented in his samples, both these gentlemen agreed, that although it was a valuable ore of copper, the mineral was not present in sufficient quantity to pay for working. Thoroughly convinced of the soundness of their advice, but disappointed at the unexpected result, Dr. Howey took no further action in the matter, ridiculing in a quiet way the earnest and persistent efforts of others to interest capital in the immense economic possibilities of this and similar deposits afterwards found. One can imagine his chagrin, therefore, and sympathize with his mortification, when subsequent development demonstrated that both these gentlemen, whose scientific attainments could not be called in question, had been rather hasty in their judgment, although from a wide experience with the composition of pyrrhotites in general, they had been right in thus expressing their opinion.

Opinions by Drs. Selwyn and Girdwood.

Dr. Howey's disappointment.

Discovery of Murray mine

Early in 1884, the Canadian Pacific Railway made a cutting for their main line through this small hill (Murray mine), about 3½ miles northwest of Sudbury, and on July 12th of the same year, Dr. Selwyn

Dr. Selwyn's opinion.

made a careful examination of the location, and, stated to the writer, some years afterwards, that he had pronounced the lode to be one of the most promising he had yet seen in Canada. No such opinion, however, was ever published, although it is quite possible that the greater facility of examination caused by the cutting for the railway, and the massiveness of the deposit thus exposed, reversed his previous judgment of the ore body in question. (1)

Other mines found.

First reports greatly exaggerated.

Form of nickel bearing eruptive.

Other discoveries soon followed, and the McConnell, Lady Macdonald, Stobie, Blezard, Copper Cliff and Evans mines were all located. At first, the wildest notions were entertained as to the extent of these deposits, and the most exaggerated reports circulated as to their value. It was even confidently asserted that these were immensely important discoveries, and would revolutionize the whole copper trade, and render other mines then in operation quite unremunerative. Rounded hills of gossan, indicating the presence of the more solid and unaltered ore beneath, occur at intervals for miles in a southwesterly direction, conforming rudely to the strike of the stratified or foliated rocks, in the vicinity. This circumstance is all that seems to have justified the early discoverers in describing the deposits as veritable mountains of solid ore, many miles in extent and hundreds of feet thick. During the interval which has elapsed since the first discovery was made, prospectors have not been idle, and their efforts have been rewarded by the location of three large belts or masses of the sulphide bearing norite. Until lately, these have been considered as entirely separate and distinct from one another, but the later geological work is tending to prove their connection as one continuous ellipsoidal band, the central portion of which is now occupied by tufaceous slates and sandstones, coloured provisionally as of Cambrian age.

History of development.

The history of the development of mining in the Sudbury district is, in the main, that of the Canadian Copper Company, for it was the

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1. A specimen collected at the time by Dr. Selwyn from the cutting on the railway at the Murray mine, was examined by Dr. Hoffmann, who says 'It consisted of magnetic-pyrites and copper-pyrites, in association with a dark gray fine-grained diorite and a grayish green chloritic schist; a few of the fragments were in parts, coated with hydrated peroxide of iron. Some specimens of the magnetic-pyrites from this deposit contained numerous flakes of molybdenite. It was found to contain after drying at 100° C., (Hygroscopic water=0·085 per cent.)

Iron	27·35
Copper	9·08
Sulphur	18·69
Insoluble matter (gangue)	36·63
Gold	mere traces.
Silver	2·187 oz. to the ton of 2,000 lbs.

(Ann. Rep. Geol. Surv. Can. Vol. I, 1885, Part M, pp. 19-21.

first combination of capital which seriously undertook the business of mining in this area, while, at the same time, having the distinction of being the only corporation, which has continued its operations without serious interruption, from the commencement until the present time.

The McAllister mine, later called the Lady Macdonald mine, (now No. 4 mine of the Canadian Copper Company's group), situated on the north side of the lake of the same name, on lot I, con. III., of the township of Snider, was the first property on which any work was done in the summer of 1885, although later in the fall, the Evans mine, about two and a half miles farther south in the same township, was opened up and some preliminary tests made. On January 5, 1886, the Canadian Copper Company was formed, with a subscribed and paid up capital of $2,000,000, which was afterwards increased to $2,500,000, to operate the Copper Cliff, Stobie and Evans mines.

Canadian Copper Co. organized.

Mining started at Copper Cliff.

On May 1st, 1886, work was started in earnest at the Copper Cliff mine, near the north end of lot 12, con. II., of McKim township, and the first shipments of ore made from the district, were obtained from the surface openings of the original Copper Cliff mine. Later on in the same year, both the Stobie and Evans mines were opened up, and these three mines together produced all the ore treated in the smelters at Copper Cliff, until the year 1898. The first blast furnace installed at the old or East Smelter was blown in on December 24, 1888, this being augmented under the same roof by a second blast furnace, which was started on September 4, 1889. During 1896, and 1897, diamond drill exploratory work was undertaken in connection with the deposits afterwards known as the No. 1 and No. 2 mines with their extensions, and in 1898, many of these openings produced a considerable quantity of high grade ore, but, with the exception of the deposit at No. 2, there was apparently no very large or continuous body encountered, for they were soon abandoned and are now completely dismantled. About the same time, what is now the largest open pit of the whole group of the Copper Cliff mines (No. 2), was started in earnest, soon supplying a very large quantity of ore, which, however, contains a considerable admixture of rocky matter. The Evans mine, although with some rather serious interruptions, continued to furnish ore until late in the fall of 1899, when it closed down, and to all appearances has been permanently abandoned. The engines, boilers and other machinery have been removed, and the rails of the spur connecting the mines with the main line of railway, have all been torn up and carried off to be used elsewhere. In the fall of 1899, preparations were made for opening up the Frood mine (No. 3), situated

First blast furnace.

No. 2 mine started.

Evans mine closed down.

a little over a mile southwest of the Stobie mine, on lot 6, con. VI., of the township of McKim, and early in 1900, this was added to the list of producing mines. During 1899, and succeeding seasons, many of the openings northwest of No. 2 mine, as well as some of the pits and shafts known as the Clarabelle group of mines, were being operated at one time or another, and added materially to the reserves of ore, but all of these were shut down in the spring of 1902, when the business of the company was being curtailed, pending reorganization and consolidation of the various interests. In July, 1900, the work of stripping at the Creighton mine was begun, and in August of the following year, ore was shipped for the first time to the roast yards at Copper Cliff. The Creighton mine is undoubtedly the largest mine in the district of which we at present have knowledge, and from the very beginning of operations, has produced very large quantities of the almost pure sulphides, with little or no rocky admixture. It is especially valuable as carrying a high percentage of nickel, with a very much smaller proportion of copper. The mine is situated on the north half of lot 10, concession I., of the township of Snider, about six miles in a straight line west of Copper Cliff station. The ore, when mined, is carried on cars over the Manitoulin and North Shore Railway, on the north side of which the mine is located, to Clarabelle junction where connection is made with the railway owned by the Canadian Copper Company. Before the opening of the Creighton mine, the Stobie had the distinction of having supplied the largest quantity of ore of all the Canadian Copper Company's mines, and with the exception of some minor stoppages, this mine was in continuous operation from the date of its opening in 1886, until November, 1901, when it closed down and has remained so ever since. The reason for this cessation of operations does not appear to be that the end of the deposit has been reached, but because the quality of ore which it supplies is not needed in the present smelting operations. The Creighton mine is at present the main source of supply, and this mine with its equipment allows for a production of between 500 and 600 tons of ore per day, and Dr. Coleman is authority for the statement that for some time in 1902, the output from this mine alone reached 17,000 tons per month. The old or original Copper Cliff still continues to supply about 1,000 tons of ore per month, obtained mainly from the 13th and 14th levels, the latter workings being 1,052 feet below the surface; but even at this depth the ore body shows no serious diminution, either in size or richness. No. 2 mine and the Frood (No. 3), complete the list of mines from which at present the supply of ore is drawn. The mines of this company, not in use at present, must not all be considered as

Frood mine opened.

Clarabelle mines.

Opening of Creighton mine.

Stobie mine.

Closed down in 1901.

Very large supply of ore from Creighton mine.

having been permanently abandoned, but the openings now utilized produce an ample supply of the sulphide material of the various grades suitable for smelting.

Increase in smelting equipment at Copper Cliff.

This activity in mining at Copper Cliff, and the steady increase in the production of ore, necessitated constant additions to the smelting equipment, as well as the erection of new and suitable buildings for the accommodation of the new blast furnaces. We thus find, that, besides the enlargement of the old or East Smelter, where three new furnaces were installed in addition to the two already mentioned, an entirely new structure known as the West Smelter, was built in 1899. At first, this building had room for only 4 furnaces, but this was quickly enlarged, and the furnace capacity doubled. The site chosen for this new building, was on the slope of the hill about 300 feet southeast of the No. 2 mine rock house, the deep valley to the south providing a convenient and ample dumping ground for the slag.

East Smelter abandoned.

Since the inauguration of this smelter, the one at the east end of the works is being gradually abandoned, and much of the old plant has already been removed to the site of the new building. The work done at this place, since the suspension of operations in the beginning of 1902, has been rather spasmodic, and has consisted mainly in the production of a low grade matte known as 'spilt matte.'

Pyritic smelting.

Thus, several of the furnaces at this smelter were being employed in producing this matte from June, 1902, until the end of the year. In addition, two of the furnaces have been engaged from time to time, making experiments in the way of smelting the ore pyritically. It is hoped, by this method, to reduce the coke to 3 or 4 per cent of the charge, by using a hot blast and an oxidizing atmosphere in the blast furnace, and utilizing the heat developed by the burning of the sulphur and iron of the ore, for the smelting. In the fall of 1900, the plant of the Ontario Smelting Works was installed by the Orford Copper Company, an organization closely related to the Canadian Copper Company. The works, as completed, are designed to further refine the first or lower grade matte, produced by the blast furnaces of the Canadian Copper Company, using as a flux, the silicious ore from the Massey Copper mine.

Installation of Ontario Smelting Works in 1900.

Formation of International Nickel Co.

Perhaps, the most important event in the development of the nickel industry, either in this district or elsewhere, occurred in April, 1902, when after negotiations, covering a period of several months, the International Nickel Company was organized under the laws of the State of New Jersey, to consolidate and control the nickel production of the world. The following properties were included in the new organization :—The Canadian Copper Company; the Orford Copper Company, with reduction works at Bayonne, N.J.; the Anglo-American Iron Company, and the Vermilion Mining Company, in Canada; the American Nickel Works, in Camden, N.J.; the Nickel Corporation, Limited, and the Société Minière Caledonienne, in New Caledonia. During 1902, and 1903, mining operations were considerably curtailed, except in the case of the Creighton mine, where the production has been brisk ever since it was first opened. This has permitted certain very necessary explorations of many of the ore deposits, by diamond drilling and testing shafts. The results of these experiments, have added very largely to the detailed knowledge, not only in regard to the size and shape of the deposits already known, but has succeeded in revealing the presence of considerable bodies of ore, whose presence had not been suspected.

Mining operations curtailed.

Such, in brief, is the record of the principal events in the development of the mining and metallurgical operations of this pioneer company, in the nickel industry in Canada. From the start, their work has always been characterized by energetic and business-like methods, and if at the present time, they seem to have gained control of more than their fair share of the available nickel bearing area, which likewise includes many of the mines producing the largest supplies of high grade nickel ore, the result must not be attributed to chance or a series of fortunate circumstances, but is rather the strongest evidence of the keen business foresight of the originators of the enterprise, and an abiding faith in the permanence of the nickel mining in this district.

Business-like methods of Canadian Copper Co.

It must not, however, be assumed that all of the available or even important deposits of nickel-copper sulphides, have passed under the control of the International Nickel Company, for besides the Victoria mines of the Mond Nickel Company, which still contain a very large reserve of high grade ore, there are many others throughout the district which are capable of economic development as more or less permanent mines. Suspension of operations, so often recorded in the history of the mining development of the district, does not in all or even a majority of cases, imply a failure in the ore supply, but is oftener to be attributed to a waste of capital, owing to lack of business judgment, and the need of a technical knowledge of the difficulties to be encountered in both the mining and smelting departments. Moreover, many of the deposits have been condemned, because they failed to give a proper return for the capital invested, when all that was available of the latter was utilized in costly experiments, to discover new methods of smelting or refining. Past experience in this district has shown that

All important deposits do not belong to International Nickel Co.

Reasons for suspension of operations.

Necessity for large reserves of ore.

success and permanency in the mining and smelting operations of any company, can only be secured by the possession of large reserves of ore, preferably obtained from different mines or deposits. In this way, not only is a constant supply of ore assured, but diversity in composition is possible. thus enabling a judicious selection of the different grades, whose mixture in the proper proportions, promotes successful and economic smelting.

Important deposits on Levack and North Nickel Range.

In addition to the deposits which are still available along the Southern Range, most of which are in various stages of development, there are other apparently very large and important ore bodies, situated along the Middle range (in Levack township); and others again on the Northern Nickel Range which are certainly worthy of close attention and which seem destined, in the near future, to be worked as mines. The lack of transportation facilities has, up to the present, prevented any deep mining work being done, but the surface indications and geological conditions are entirely favourable to the existence of large ore bodies, which, although perhaps not attaining the phenomenal dimensions of the Creighton mine, will nevertheless prove of sufficient magnitude to form valuable mines.

Henry H. Vivian & Co.

Beginning of operations at Murray mine.

The incidents attending the discovery of the deposit which was afterwards known as the Murray mine, have already been related, as also the fact that it was located over a year previous to either the Copper Cliff or Stobie mines. In spite of this circumstance, however, and its advantageous situation on the main line of the Canadian Pacific Railway, no mining of any importance was done in connection with this property until early in the year 1889. During the whole of this season, however, it was prospected under bond by H. H. Vivian & Co., of Swansea, Wales, and in October, of the same year, it was sold outright to this company by the original owners. The mine is situated on the north half of lot 11, con. V., of McKim township. All the necessary machinery, buildings and other adjuncts were installed, and preparations made for carrying on the business of mining on an extensive scale.

Smelting at Murray mine.

The first blast furnace at the Murray mine was blown in about the end of September, 1890, and put to work on some ore which had been previously roasted. The general practice followed by this company in their smelting operations, consisted in the production of a comparatively low grade blast furnace matte (averaging 9.4 per cent nickel and

4.7 per cent copper), thus preventing an undue loss of the metals in the slag, and subsequently bessemerizing this into a second or higher grade matte (averaging nearly 75 per cent of the combined metals or about 49 per cent nickel and 26 per cent copper). For this second concentration of the metallic contents, the Vivians were the first to make use of the Manhés furnace or converter in 1891. Mining and smelting operations were continued, although with some minor interruptions, from 1889 until 1894, when the works were finally closed down. Between August, 1896, and January, 1897, however, the smelter was engaged in producing matte from about 6,000 tons of ore which had been roasted by the Vivians. This product was shipped to Mr. Joseph Wharton, of Camden, N. J., to whom it had been sold.

Cessation of operations.

Purchase of Murray mine by Vivians of great promise to whole district.

The purchase of the Murray mine by this old established and well known firm of Welsh smelters, was regarded by all as marking a distinct epoch in the history of nickel mining in Canada. Their wide experience in all branches of metallurgical industry, seemed to augur well for the success, not only of their own individual enterprise, but their presence in the district, promised to be of immense assistance to others similarly engaged in the mining and smelting of these nickel and copper sulphides. The difficulties which always attend the initiation of a new undertaking, were in evidence from the very beginning of the business of nickel mining, and were of that nature, which required the exercise of just such ripe technical knowledge as the Vivians were sure to possess. Moreover, such a significant acknowledgment of the success and permanence of nickel mining in Canada, on the part of a firm whose sphere of activity in mining and smelting had extended to all parts of the known world, could not fail to have a most marked influence on all subsequent mining operations in the district. It was, therefore, to say the least, bitterly disappointing, that from the very outset, a seeming lack of energy, and often even of ordinary business ability, on the part of those who had control of the work, was a subject of common remark, being in marked contrast to the alert methods characterizing the operations of the rival corporation, the Canadian Copper Company. This was evident in almost every department of the work, and the apparent lack of technical knowledge and business capacity on the part of this firm, from whom so much had been expected, could not be very well understood by the ordinary observer. On the other hand, the management entrusted with the conduct of affairs at the mine, complained of want of interest and attention on the part of the authorities in England, but, whatever the real cause or combination of causes, the enterprise was not attended with the success anticipated, and which should have been reasonably

Cause of failure.

Apathy of management.

expected. The final decision of the company to close down and withdraw from the business of mining in Canada, came as a distinct shock to all those who were interested in seeing the permanency of the nickel mining established. The failure of these operations must not, therefore, be attributed, as some have supposed, to the diminution in depth of the ore body or to abundant rocky admixture, although these, no doubt, contributed to a certain extent to bring about the undesirable result. It seems altogether reasonable to suppose that a considerable quantity of ore is still present, both in the lower levels of the mine, as well as below these workings at depths which have not yet been reached by the mining explorations so far undertaken, which could be profitably mined in conjunction with other deposits. In this respect, the Vivians were at a manifest desadvantage as compared with the Canadian Copper Company, the varied composition and character of the ores from whose different mines permitted, and even favoured, the mixtures which are seemingly so essential for the successful and economical smelting of these sulphide ores. In addition to the Murray mine, the Vivians owned the nickel and copper deposit known as the Lady Violet mine, situated on the north half of Lot 1, con. IV., of the township of Snider, about 1½ miles southwest of the Murray mine. The mining, however, undertaken at this locality consisted chiefly of stripping, the sinking of trial shafts, and other preliminary development work. A blacksmith's shop and some temporary residences were the only buildings erected.

Ore still present in lower levels of mine.

Necessity for various grades of ore.

Lady Violet mine.

Some rather extensive diamond drill exploration work was subsequently undertaken by order of the Board of Directors in England, at both the Murray and Lady Violet mines, but unfortunately, the different sites for the drill, as well as the angles of inclination and direction of the bore holes, were determined by some of these same directors in England, whose only means of guidance in this selection, seems to have been maps of the two properties in question, but without any very extended personal knowledge of the actual geological conditions prevailing at these places. As might have been expected, from operations carried on under such adverse conditions, no important ore bodies were encountered, nor was any information of material value obtained, which might be of assistance either to the owners or to any prospective buyer. The diamond drill used belonged to the Ontario government, and was loaned to the Vivians under the usual conditions of working in 1898. Boring was begun on the 2nd of December, 1898, and the work continued until the 16th of June, 1899, the number of days of actual boring being 212, of 10 hours each. In all, eight holes

Diamond drill exploration at Murray and Lady Violet mines.

Cost of diamond drilling.

were put down, having an aggregate depth of 1,146 feet, which cost on an average $2.65 per foot. (1)

Caretaker at Murray mine.

Since the abandonment of active mining, the property has been under the charge of Mr. G. H. Behenna, who has been continuously employed looking after the various buildings and machinery, while a pump has kept most of the levels comparatively free from water.

Dominion Mineral Company.

Location of Blezard mine.

The Dominion Mineral Company commenced mining operations in the summer of 1889, on a deposit of nickel and copper ore known as the Blezard mine, occurring on lot 4, con. II., of Blezard township, about 1¼ miles north of the Stobie mine, at the southern edge of the Main or Southern Range of norite, which here comes in contact with the older diorites and hornblende schists. A smelter was soon built, with a furnace capacity of 120 to 150 tons daily. Four shafts were sunk at this mine, the deepest of which seems to have reached a point 172 feet below the surface. Most of the ore secured, however, was by means of a series of large open pits which are at present filled with water. The "kies" or metallic portion of the ore thus obtained is said to have averaged about 4 per cent nickel and 2 per cent copper. For reasons which have been differently stated, mining operations were discontinued in the summer of 1893, and have not been resumed since. The smelter, however, at this mine, was kept running until July, 1895, on ore brought chiefly from the Worthington mine. The total production of ore cannot be accurately given, but the figure of 100,000 tons is certainly somewhat below the actual output. The Worthington mine, also worked by the same company, is situated at a station of the same name, on the Sault branch of the Canadian Pacific railway, twenty-five miles west of Sudbury. The mine itself, consisting of two shafts, lies close to the line between lots 1 and 2, con. II., of the township of Drury. It was discovered at the time of the construction of this branch by Mr. James Worthington, one of the railway contractors. Actual mining was started on this property in the summer of 1890, and continued without much interruption until the middle of September, 1894, when operations ceased, and with the exception of a short time in 1902, when the mine was pumped out for purposes of inspection, no work of any consequence has since been done. From the two shafts, one of which reached a depth of 100 feet, and the other 175 feet below the surface, as well as from two adjoining

Erection of smelter.

Composition of ore.

Cessation of operations.

Production.

Discovery and location of Worthington mine.

Depth of mining.

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(1) Ann. Rep. Bur. of Mines, Ont., 1901, pp. 53 & 56.

Production of Worthington mine.

stopes and connecting levels, a considerable amount of unusually high grade ore was obtained, which has been estimated by Dr. Coleman at 25,000 tons. The pyrrhotite occurring at this mine is often phenomenally high in nickel, chiefly owing to abundantly disseminated pentlandite, and the first recognition of this mineral in the district was by Dr. T. L. Walker, in the ore procured from this mine by the writer in 1891, and to which reference has already been made. The analysis of this pentlandite by Walker showed 30 per cent nickel, but an examination of some large masses of ore obtained at a depth of 85 feet below the surface, and consisting of pyrrhotite with a considerable proportion of pentlandite, which could be readily discerned, showed 17·48 per cent of nickel. In 1891, a shipment of raw ore was made from this mine of 123 tons, which contained 10 per cent nickel and 3 per cent copper. Large masses of practically pure chalcopyrite were also obtained, and a considerable quantity of such ore is stated by Manager Attwood to have been shipped, assaying 18 per cent copper and 2·5 per cent nickel.

Character and composition of ore at Worthington mine.

Work at Cameron mine.

In the fall of 1895, some development work was done by this same company, at the Cameron mine, on lot 7, con. 1, of Blezard township, nearly two miles southwest of the Blezard mine. A shaft was sunk a distance of 65 feet with a drift 66 feet in length. The real reason for the cessation of work at both the Worthington and Blezard mines is very difficult to ascertain, but bad business management was responsible in large part for many of their difficulties during these mining operations. Individual members of the company state that the present idleness of these properties is because no decision satisfactory to all parties can be reached by the board of directors, so that working under these conditions is impossible, and they would be inclined to sell.

Reasons for cessation of mining.

Some of the other companies who carried on mining and in some cases smelting operations for a time, shortly after the recognition of this area as a mining district deserve a passing mention in this connection.

Work by Algoma Nickel Co.

One of these, the Algoma Nickel Company, in 1891, under an option secured from the owners of the property, sank four shafts varying in depths from 12 to 35 feet and aggregating 84 feet in all, besides some smaller openings or test pits on lot 11, con. V., of the township of Lorne. No large body of ore was, however, met with as a result of this development work, the sulphides apparently occurring as unusually rich impregnations, which, if continuous, might prove an economic possibility. These sulphides occur in connection with what is seemingly the southwestern extension of the same mass or band of norite on which the Worthington and Mitchener mines are situated. Work was abandoned, leaving ore piles aggregating about 500 tons in weight. Assays of an average sample in the laboratory of the Survey showed 1·95 per cent nickel, with traces of cobalt.

Drury Nickel Company.

The Drury Nickel Company purchased the deposit known as the Chicago or Travers mine in 1890, and began active mining in February, 1891. This mine is situated on lot 3, con. V, of the township of Drury, about 5 miles north of Worthington station, on the Sault branch of the Canadian Pacific railway. Most of the ore was mined by means of open cuts, one of which had a depth of 30 feet, length 60 feet and width 30 feet, from the bottom of which a shaft 8 by 12 feet was sunk to a depth of 60 feet. Another open pit measured 40 feet in length, 80 feet in width and 30 feet in depth. From these openings 3,500 tons of ore were obtained, and reduced to matte in a water-jacketed furnace capable of treating 60 tons in 24 hours. A roast-yard was prepared, suitable buildings erected, and the plant installed necessary for permanent mining, but in spite of all this, the mine closed down in 1892. In 1893, after lying idle for nearly a year, some additional mining and smelting was undertaken, but this was also soon abandoned. On May 20, 1896, work was again resumed, the company being reorganized under the name of the Trill Nickel Mining and Manufacturing Company, and the deposit itself was rechristened the Inez mine. An elevated tramway, 4½ miles long, was built from Worthington station, for conveying supplies to the mine, and the product of the mine, in turn, to the station. It was possible, by means of this tramway, for a single horse to haul two cars, each containing two tons, and to make two round trips, each way, daily. Mining and smelting continued briskly again, for a while, but before August, 1897, work was again stopped, and has not since been resumed.

Mining at Chicago or Travers mine.

Smelting.

Trill Nickel Mining and Man'fg. Co.

Inez mine.

Levack mines.

From time to time, mention is made of the 'Big Levack properties,' thus referring to certain deposits of nickeliferous pyrrhotite, which were discovered early in the history of the district in the township of Levack, but none of which have been sufficiently developed to be dignified by the name of "mine." From time to time, however, considerable work has been done and examinations made, with a view to possible purchase, but for various reasons, the properties are at present lying idle and without any present prospect of being opened up in the near future. The deposits in question are situated along the northern junction of what has sometimes been called the Windy lake eruptive or Middle Belt of the nickel-bearing norite, although it is possible that this is a portion of the huge ellipsoidal band, and the south-

Windy lake eruptive.

Surface indications among the best in the district.

western continuation of the Northern Nickel Range. The surface indications are undoubtedly among the best in the district, and the development work so far undertaken has exposed a very large amount of almost pure nickeliferous pyrrhotite, with little or no rocky admixture. The ore-body has the additional advantage that chalcopyrite forms only a comparatively small proportion of the whole. The first, and probably the most extensive mining exploration work in connection with these properties, was undertaken in 1891, and a report made by Mr. A. Merry, of H. H. Vivian and Company, for the owners of the property. This work consisted of extensive stripping, and the removal of portions of the overlying drift material, the opening up of numerous cross cuts, trenches and test pits. The average assay of a number of typical samples, made by Mr. Merry, showed the presence of 3.86 per cent of nickel in the pyrrhotite, with 0.81 per cent of copper. Assays made in the laboratory of the Survey show the nickel to vary from 1.96 to 4.13 per cent, the lower figure containing considerable gangue, while the higher results were obtained from the solid, coarse-grained pyrrhotite.

Character of ore body.

Examination and work by Alfred Merry.

Composition of Levack ores.

Exploration by Mond Nickel Co.

Early in 1901, some of these locations were examined by means of diamond drill exploration, under option by the Mond Nickel Company, but to the disappointment of all who were concerned in the welfare of the district, this company decided to abandon their option, and the property was again thrown on the market. It is manifestly unwise, as a rule, to condemn as worthless the testimony afforded by diamond drill exploration, especially when such work is under the superintendence of men thoroughly experienced in the mode of occurrence of the class of deposit to be tested, but an inspection of the work performed at this time, seems thoroughly convincing, that much of what was done added very little, if any, information to what we already possessed in regard to these deposits, or than can be secured without such costly assistance. We are, therefore, still in the dark as to whether or not there are any large or continuous bodies of ore at these places, and if the former, as to their most likely disposition. All geologists who have visited these deposits, and especially those who have had wide experience in the district, are agreed that large and valuable ore-bodies are likely to occur at this place. The rock is the usual norite, with which all the other mines of the district are associated, while the contact is well and sharply defined, and the differentiation pronounced. The area covered by the nickel-bearing norite is very large, and no other deposits have been found in connection with this eruptive. The angle of dip to the southeast is unusually low for the district, and this fact has to a large extent prevented its successful exploration. The development work, as well as the borings undertaken by the diamond drill,

Diamond drilling not always satisfactory.

Probability of large ore bodies in Levack.

Suggestions for mining exploration work.

seem to incline the casual observer to the conclusion that the deposit is a 'pancake' and has no great depth or permanence. A careful study of the attitude of the outcrops of rock, as well as their surface outline in the immediate vicinity of the sites chosen for drilling purposes, is convincing that no deep deposit need be expected in their vicinity, while on the other hand, it seems reasonable that the main body of the sulphides is concealed beneath the drift, at the base of the hill, where no trials whatever have been made. A shaft sunk here and continued with the granite-gneiss as a foot-wall, with drifts outward towards the main mass of the norite, would show definitely and finally not only if any large and continuous ore body is present along this line of junction, but at the same time would secure a considerable amount of ore, which could afterwards be used.

Location and work at Beatrice or Sheppard mine.

In 1891, a shaft was started on the Davis property, known as the Sheppard or Beatrice mine. This deposit is situated along the north-eastern extension of the same line of junction as the Blezard mine, between the norite and greenstone. It is on lot 1, con. III., of Blezard Township, nearly two miles north-east of the Blezard mine, with which it is connected by wagon road. The shaft, 10 by 12 feet, was sunk to the depth of 100 feet, with three small drifts, aggregating 34 feet. Work, however, was not continued after April, 1893.

Operations by Emmens Metal Co. at Gersdorffite or Macdonell mine.

In the same year, (1891), a shaft was sunk and considerable development work done by the Emmens Metal Company, on the property afterwards known as the Macdonell or Gersdorffite mine, situated in the southeast corner of lot 12, con. III., of the township of Denison, and about one mile and a half northeast of Worthington station. This locality is remarkable as having furnished the first specimens of the rich nickel minerals, niccolite and gersdorffite in the district, but as no large body of ore was discovered, mining operations soon came to an end.

Trillabelle mine.

In 1894, the deposit known as the Trillabelle mine was opened, and a shaft 60 feet in depth sunk on the deposit. This mine is situated on lots 10 and 11, con. III., of the township of Trill, and is connected by wagon road, by way of the Inez or Travers mine, with Worthington station, which is about 13 miles distant.

Mining at Kirkwood mine.

In 1898, the deposit which was named the Kirkwood mine, situated on lot 8, con. III., of the township of Garson, at the southern edge of the main or southern belt of norite, along the same line of junction as the Blezard and Beatrice mines, was opened. Three shafts were sunk, the deepest of which was rather less than 50 feet. A substantial rock house and other suitable mining buildings were erected, but for lack of sufficient capital the work has not proceeded further.

Great Lakes Copper Co. purchase of and work at Mount Nickel mine.

On October 5, 1899, the Great Lakes Copper Company was organized, and purchased the property known as the Mount Nickel mine, comprising lots 5 and 6, con, II., of the township of Blezard. They also purchased what was known as the "Trill Property," consisting of lots 9 and 10, in cons. III., and IV., of the township of Trill in the district of Algoma. The Mount Nickel mine was chosen as the scene of the first mining operations, and this deposit was developed by means of two open cuts and a shaft, which eventually reached a depth of about 165 feet, with certain levels and drifts, from all of which considerable ore was obtained. It is also stated that diamond drill explorations subsequently undertaken revealed the presence of a good supply of ore. The mine was equipped with all the machinery and other appliances for carrying on extensive mining operations. The smelting works were built from original designs, by Anton Graf, of Vienna, and it was proposed to produce high grade matte at one operation, from ores which had received no previous roasting. This method of smelting failed, and in May, 1901, all operations ceased, and have not been resumed since.

Equipment and smelting at Mount Nickel.

Work by Hoepfner Refining Co. and the Nickel Copper Co.

In the latter part of 1899, it was announced that a strong company, under the title of the Hoepfner Refining Company, with a capital of $10,000,000, had been formed in Hamilton, to refine nickel-copper mattes and zinc ores. These metals were to be recovered by electrolytic methods discovered by Dr. Carl Hoepfner. The Nickel Copper Company, of Hamilton, also organized about the same time, were to furnish the necessary supply of nickel-copper matte. Unfortunately, however, Dr. Hoepfner was unable to so perfect his methods as to permit of its economic application on a large scale, and the Nickel Copper Company took the matter of experimenting into their own hands. The services of Mr. Hans A. Frasch were obtained, who devised what is known as the "Frasch Process." This method likewise, although possible under ordinary conditions of laboratory practice, as was demonstrated at a public exhibition held on September 3, 1900, was not capable of commercial application. The operations of the Nickel Copper Company came to an end in 1901, owing to the complete failure of the new self roasting plant erected near Worthington station.

Operations ceased in 1901.

LAKE SUPERIOR POWER COMPANY.

Proposals for work by Lake Superior Power Co.

For some time after the opening of the pulp mills at Sault Ste. Marie, the Lake Superior Power Company were content to manufacture mechanical pulp, but discovering that there was a large and growing demand for sulphite pulp, it was decided to at once enter upon its manufacture. The proximity of the sulphide deposits at Sudbury, suggested that the sulphur which was necessary for the production of this pulp might be most profitably extracted from these ores, and at the same time yield a by-product of very great value. The preliminary experiments with the nickeliferous pyrrhotite were convincing that sufficient sulphur dioxide could be procured from this mineral by roasting, while at the same time the roasted ore or residue, consisting essentially of a mixture of iron and nickel with only a comparatively small percentage of sulphur, could be mixed with lime and charcoal and smelted in electric furnaces to ferro-nickel. It was intended at the time to employ this alloy in the production of steel rails, which it was proposed to manufacture in large quantities. An inspection of all the available deposits of nickeliferous pyrrhotite seemed to indicate that the property afterwards known as the Gertrude mine was peculiarly adapted to meet the necessities of the case in hand. In 1899, therefore, the Lake Superior Power Company purchased this mine, and immediately proceeded to develop the deposits which were situated on the S. ½ of lots 3, 4 and 5, of concession I, of the township of Creighton, a little over twelve miles west of Sudbury. The preliminary examinations and first development work showed an unusual predominance of a high grade nickeliferous pyrrhotite, with comparatively little of the objectionable copper in the form of intermixed chalcopyrite. As mining operations proceeded, however, more chalcopyrite was encountered, and the deposit gradually assumed the usual characteristics of those elsewhere in the district, and the copper contents assumed too large a proportion to permit of the successful carrying on of the first proposal. Repeated experiments were made with many car loads of raw material shipped to the works at the Sault for this purpose, but it was finally decided to adopt the ordinary processes of smelting in use elsewhere throughout the district, producing a blast furnace matte averaging about 29 per cent of the combined metals, the proportion of nickel being about double that of the copper.

Manufacture of ferro-nickel.

Purchase and beginning of operations at Gertrude mine.

Large experiments at "Sault."

Ordinary smelting methods adopted.

In 1900, the development of the Gertrude mine was continued, but the necessity of transportation facilities greatly hampered these operations. Two shafts were sunk, one attaining a depth of 120 feet, and the other of 80 feet, with several levels and drifts. In the spring of 1901, the Manitoulin and North Shore railway reached this mine, and work was conducted much more energetically. Roast yards were prepared, and the erection of a smelter commenced. In July of that year, the Elsie mine on the S. ½ of lot 12, concession V., of McKim, and about half a mile southwest of the Murray mine, was open-

Mining development at Gertrude mine.

Opening of Elsie mine.

ed up. The ore was shipped in 50 ton steel cars to the roast yards at the Gertrude mine, and the first shipment of ore was made to this place on the 26th of October, 1901, on the completion of the switch, which connects the deposit with the main line of the Manitoulin and North Shore railway. The smelter at the Gertrude mine was finished in June, 1902, and afterwards ran steadily throughout the year, converting 100 to 160 tons daily into standard matte. In November, 1902, all work was suspended at the Elsie mine. to permit of the needed removal of some of the mining buildings, whose safety was threatened, by a continuance of the mining work. Later, in 1903, the whole of the mining operations in the Sudbury district shared the same fate in common with the other industries, operated by the same company, at the time of their failure.

Smelting at Gertrude mine.

Cessation of operations.

MOND NICKEL COMPANY.

Discovery of carbon monoxide process.

In 1889, Dr. Ludwig Mond, F. R. S., in collaboration with Dr. Carl Langer, while carrying on certain experiments for determining a suitable method for eliminating the carbon monoxide gases containing hydrogen, made certain observations, which eventually resulted in the discovery of what has since been known as the Mond or carbon-monoxide process, for separating metallic nickel from copper, etc. In this process, there were many technical difficulties to be overcome, so that although a patent was applied for on the 12th of August, 1890, it was some years before it had reached such a stage as demonstrated its possibilities of commercial success. In 1892, an experimental plant, on a large scale, was erected at Smethwick, near Birmingham, England, and after several years of patient work, during which time the plant had to be several times remodelled, in order to meet all the requirements of this somewhat delicate process, it gradually assumed its present shape. In 1898, it had reached such a state of perfection, as to afford the most convincing proof, that the process was able, not only to compete successfully in regard to cost of operation, but at the same time, the metallic nickel produced, showed on analysis, a higher degree of purity than had yet been possible by any other known process.

Perfection of method and erection of refineries.

The success of the method being thus assured, Dr. Mond began at once to make inquiries, with a view to obtaining an unfailing supply of nickel ore. Experiments conducted on the nickel and copper sulphide ores, seemed convincing, that such were peculiarly suited to treatment by the Mond process, so that it was decided to buy one or more of the best locations which were then available in the Sudbury Mining District. At this time, and for some years previously, it was a

Purchase of Victoria mine.

matter of common gossip throughout this area, that the McConnell mine or property, in the township of Denison, was one of the largest deposits of high grade ore which had yet been found, and attention was, therefore, directed to it with a view to possible purchase. After some negotiations, and a thorough investigation of the merits of these deposits, Dr. Mond decided to acquire these properties, and accordingly, in the summer of 1899, the necessary transfer was made. These mining locations had been under development for some time by their former owner, Mr. Rinaldo McConnell, and at the time they were sold to Dr. Mond, explorations were being carried on by means of the Ontario government diamond drill, with a view to determining more definitely the position and extent of the various ore-bodies. The change in ownership, however, did not affect the progress of the work, which began on July 10, and finished on November 21, 1899. In this time, seven holes were bored, the aggregate number of feet being 994, at an average cost of $1.75 per foot. In addition, two other drills owned by Dr. Mond were engaged more or less continuously during this and the two succeeding years, investigating these and other mining locations, in which Dr. Mond was interested. The main shaft and mining buildings of what was henceforth to be known as the Victoria mines, are situated on the north half of lot 8, con. IV., of the township of Denison, while the smelter, offices and official residences, were built on the north half of lot 8, con. II., of the same township, close to the "Sault" branch of the Canadian Pacific railway, and a little over two miles south of the main openings.

Diamond drill exploration.

Cost of diamond drilling.

Location of mine and smelter.

Beginning in 1899, the work of opening up these deposits proceeded as rapidly as circumstances permitted. Extensive stripping of the deposits and other preliminary development work was undertaken; roads were opened up; a roast yard was levelled and otherwise prepared, and the necessary timbers secured for the numerous extensive structures contemplated.

Opening up of deposits.

During 1900, this work was continued, special attention being given to equipping the mines and smelter, the site of the latter being chosen close to Fairbank creek, on the Sault branch, 22 miles west of Sudbury. An aerial tramway, 11,000 feet in length, was installed by the Trenton Iron Co., of Trenton, N. J., to convey the ore from the rock house at the mines to the roast yard, which was first located close to the smelter.

Erection of smelter.

Aerial tramway.

On the 16th of October, 1900, the Mond Nickel Company, Limited, of London, Eng., was authorized, by license of the Lieutenant-Governor, to carry on business in Ontario. The incorporation of this company, with a capital of £600,000, was for the purpose of acquiring all

Incorporation of Mond Nickel Co.

the above property, plants, patents, and smelters belonging to Dr. Ludwig Mond in the Sudbury district.

Building up of Victoria Mines.

Plant of the most modern type, for roasting, smelting, and bessemerizing the ore, was erected at Victoria Mines, under the direction of Mr. Hiram W. Hixon, formerly of the Anaconda Company, this equipment being the most complete and conveniently arranged, which had, up to that time, been installed in the district. In addition, substantial offices and tasteful dwellings, with all modern conveniences, such as water and electric light, have been erected for the accommodation of the staff and their families, and the site of pre-existing swamps and rocky hummocks was quickly filled in, levelled and transformed into an important village and business centre.

Beginning of mining and smelting operations.

Early in 1901, the mine was in complete working order, and beginning with February, ore was regularly raised and transported by means of the aerial tramway, to the roast yard. The smelter shortly afterwards commenced to turn out matte, by the Bessemer process, this product averaging about 80 per cent of combined nickel and copper, the former metal being usually present a little in excess. On 1st July, 1901, the head house or landing station at the roast yard was struck by lightning, and before adequate assistance could arrive, was burned to the ground. This temporary breakdown of the cable system, although greatly retarding mining operations at the time, was really a blessing in disguise, as it resulted in a decision to abandon this roast yard, the position of which on the immediate outskirts of the village, had been a source of annoyance and inconvenience to the residents, who during certain conditions of wind and weather, suffered greatly from the sulphurous fumes given off by the burning piles. The new site chosen, consisted of a flat about half way between the smelter and the mine, which could be easily levelled, drained and otherwise prepared, this location being much more spacious and suitable in every way, than the roast yard it was proposed to abandon.

Breakdown caused by lightning.

Removal of roast yards.

Temporary curtailment of operations.

During the winter of 1901 and 1902, the operations of this company, at the Victoria mines, were greatly curtailed, but the completion of the refining works in England, and the beginning of operations on a large scale at these works in April, 1902, gave a fresh impetus to all departments of mining activity. During the summer of 1902, the North Star mine, situated on lot 9, cons. II and III., of the township of Snider, and the Little Stobie mine, on the north half of lot 6, con. I., of the township of Blezard, were worked by this company. The ore, amounting to 4,724 tons, obtained from the North Star, and 1,584 tons from the Little Stobie, was shipped to the Victoria mines for treat-

Operations at North Star and Little Stobie mines.

ment. The bessemerized matte, as quickly as produced by the smelting works at Victoria mines, was shipped to Clydach, near Swansea, in Wales, where extensive works had been built for its treatment, calculated for an annual production of from 1,000 to 1,500 tons of metallic nickel, and 4,000 to 6,000 tons of copper sulphate. These works have been so designed as to render future extension easy and economical. The property at Clydach, including about 33 acres, on which the works are erected, has a frontage on the Swansea Valley canal, giving easy access to the port of Swansea, and is connected by a siding to the Midland railway. After a year's steady production from both mines and smelter, all activity ceased in December, 1902, and although most of the higher officials were retained in office, no mining work of any consequence was undertaken until early in the spring of 1903, when work was again resumed and continued until November of the same year, when operations were again discontinued. It is currently reported that the real reason for these frequent interruptions in the mining operations, was due to certain defects in the plant at the Clydach refining works, and it is also rumored that after a recent breakdown in the plant, there were over twenty cases of poisoning from the escaping gas, which resulted in several fatalities. It is confidently expected that a remedy will soon be found for this serious condition of affairs, and that the necessary alterations in the plant will again permit of its operation on an extensive scale, thus insuring a resumption of work at the Victoria mines.

Capacity of refinery at Clydach, Wales.

Location of refinery.

Causes of cessation of mining.

The history of the development of mining in the Sudbury district, has not, therefore, been an unbroken record of brilliant successes, but often quite the reverse has been the rule, and as may be noticed in the preceding pages, the number of companies who for different lengths of time have operated in this area, already constitute a formidable list. These failures, and the causes which have operated to bring about this untoward result, serve however to bring into strong relief, the gallant and successful struggles of the only company, which has been able to surmount the various difficulties to which the other organizations have successively succumbed; at the same time, strengthening the belief, that the crisis has been passed, and the industry has at last been established on a firm and permanent basis. It is true that certain details in regard to the extraction of the nickel are still in the experimental stage in order to determine, if possible, a more economical method, but there is no doubt whatever, that the business of the mining and smelting of nickel, is not only in a satisfactory condition, but has reached such phenomenal dimensions, that operations in other countries have, in consequence, been either greatly

History of development not a series of successes.

Credit to Canadian Copper Co.

Sudbury District greatest producer of nickel in the world.

curtailed, or have ceased altogether, so that at the present time the supremacy of the Sudbury mining district as the world's greatest producer of nickel is unquestioned.

Reasons for first failures.

It may be well, in passing, to state some of the reasons which have contributed to the failures, which have been so frequently recorded in connection with the establishment of the Sudbury nickel industry. For some time after the beginning of mining work in this region, the world's annual consumption of nickel did not exceed 700 or 800 tons of the pure metal, which amount could readily be produced by any one of the three companies, then operating in the district. The demand for nickel was, therefore, so small and uncertain, that before the discovery was made of its advantageous employment as an alloy with steel, especially in the manufacture of armour plate, no great future seemed assured for the nickel industry, and even with this distinction in its favour, no very marked increase in the demand for nickel could be noticed, and it took a number of years more before the consumption had increased to 1500 tons per annum. By the time, however, this latter figure had been reached, it was certain that a constant and ever increasing demand for nickel was assured, on account of its general use in all kinds of steel, where strength combined with lightness, were the important factors. At the present time the consumption of nickel exceeds 10,000 tons per annum, and exhaustive experiments now being undertaken under the auspices of the International Nickel Company, are stated on the best authority, to give strong evidence of the superiority of nickel steel in bridge building, so that a much larger demand for nickel can be looked for in the immediate future. In addition, the recent decision of the Pennsylvania railway, to use nickel steel rails, and the award of a contract for 9000 tons of the same to carry 3·50 per cent nickel, by this vast and progressive corporation, will no doubt give a fresh stimulus to the demand. The only anxiety which now exists, and which has often been urged against any large employment of nickel steel, relates to the sources of supply, and to the possible exhaustion of the nickel deposits now known to exist. All authorities are, however, in substantial agreement, that the supply of high grade nickel ore, contained in the Canadian deposits is practically unlimited, and at least amply sufficient for many years to come, to supply the requirements of even much more extensive smelting operations than are now carried on in the Sudbury district. Besides, a demand for larger quantities of nickel will stimulate prospecting, not only in this region, but also in areas of similar crystalline rocks, to be opened up in a very short time by the Grand Trunk Pacific and its branches, as well as by the Temiscaming and Northern Ontario railway, with the probable result that many more new deposits will be discovered.

Small consumption and demand.

More extended use in alloy with steel.

Nickel steel experiments.

Contract for nickel steel rails awarded.

Deposits practically unlimited.

New deposits likely to be found.

Another fact, which has contributed to a considerable extent to bring about the failure of some of the Sudbury mining concerns, was the assumption by interested parties, that each individual deposit, of which they had the good fortune to obtain possession, was a mine, capable of producing a permanent and unlimited supply of nickel ore of the desired grade, the ore-body extending to unknown depths, and increasing both in quality and quantity with its downward extension. With such confidence in the size, permanency and suitability for smelting operations of the ore-bodies, it is not surprising that very often no special effort was made to obtain control of other available sources of supply, which were sure to be needed when extensive and long continued refining operations were in progress.

The assumption that all mines possess unlimited supplies of ore another reason for failures.

A third cause, which perhaps assisted more than any other to bring about the frequent suspension in mining and smelting operations already recorded, was the lack of the necessary technical knowledge and experience on the part of those who had the management of many of the organizations. The strong necessity of such information, in every department of mining and smelting, needs no special explanation or emphasis, but it was more than ever required for the successful treatment of these particular sulphide ores. Thus, some of the companies engaged in mining in the vicinity of Sudbury, succeeded in reaching the stage of producing matte, but even these were obliged to sell this unfinished product to the various refiners, at prices which usually came far from realizing their expectations in this respect. The refiners were accused of reaping all the profits, which should have been shared with the producers, so that very early in the history of the region, it was patent to everyone, that to share in the full benefits of the industry, the same individuals or company must control the whole of the operations necessary to manufacture the finished product. Acting on this knowledge, therefore, many of the corporations engaged what was considered the most expert metallurgical advice, and numerous experiments were undertaken, to determine an effective and economic process, by which the nickel and copper could be extracted from these ores, and afterwards separated from one another. In this manner, the too often very limited resources of these companies, were taxed to the utmost, and any failure, even in the preliminary trials, to yield the decisive and satisfactory results looked for, often resulted in the closing down and practical abandonment of the mines and works concerned. Finally, in more than one instance, the absence of sound business methods, assisted very materially to bring about some of the disastrous failures, which have been recorded in the foregoing pages.

The need of technical experience has caused most failures.

Refiners said to reap most of the profits.

Companies should produce finished article to enjoy the full benefit.

Unsound business judgment caused some failures.

GENERAL PHYSICAL FEATURES.

"Sudbury Mining District" not an electoral subdivision.

The expression "Sudbury Mining District," was applied as a term of convenient reference, soon after the discovery of these valuable mineral deposits, to designate that particular tract of country, immediately surrounding, and tributary to the town of Sudbury. It must not, therefore, be confounded with other areas in Northern Ontario, to which the term "district" has been applied, and which have been thus set apart, with definite boundaries, for electoral and other purposes. Roughly speaking, it may be described as extending from Wanapitei lake and river on the east, to Onaping and Worthington stations on the west. On the north, it may be considered as embracing the recently discovered iron deposits in Hutton township, while southward, the commencement of the Laurentian gneiss, is believed to limit important mineral discoveries in that direction.

Definition of limits of Sudbury District.

Location of the town of Sudbury.

The town of Sudbury is a creation of the Canadian Pacific railway, coming into existence, at the time of its construction in 1882, and increasing in importançe, by reason of its being chosen as the junction point for the branch line to Sault Ste. Marie. It is distant on the main or transcontinental line of this railway, 442.7 miles from Montreal, and 322.4 miles from Ottawa, the capital of the Dominion of Canada.

Outlines of areas of nickel bearing eruptive.

The area in which workable deposits of nickel and copper are now known to occur, extends from the southeast corner of Snider township (Evans mine), northwest to the central part of the township of Levack, a distance of about 20 miles; in a northeasterly direction, it reaches from the township of Drury, to Wanapitei lake, a distance of about 40 miles. The mines which have actually produced ore for smelting or shipping purposes are, with the exception of the Worthington mine, all connected with that portion of the main mass or belt of norite, which stretches from the old Inez or Chicago mine, in the township of Drury, to the Blezard mine, a distance of abut 26 miles.

Description of township and method of survey and sub-division.

The area contained in the two accompanying map-sheets (Victoria mines and Sudbury), and comprising portions of the district of Algoma and Nipissing, has all been subdivided into townships and lots of the more recent form adopted by the Crown Lands Department of Ontario. With few exceptions, each of these townships measures six miles square, the area thus embraced being thirty-six square miles. Each township is divided into six concessions, by east and west lines, run astronomically, which are designated by the Roman numerals, the order of numbering being from south to north; while the concessions themselves are subdivided into twelve lots, by true north and south lines, which carry the ordinary Arabic figures, numbered from east to west. Each lot, therefore, measures one mile from north to south, and half a mile from east to west, thus containing an area of 320 acres. Only every alternate lot line is cut out through the woods, the intervening boundary being marked by posts on the concession lines. The lines are all supposed to be run astronomically, although in some cases, no allowance having been made for the convergence of meridians, considerable error and confusion have resulted. Sometimes the surveys of these townships have not been done as carefully or accurately as might be desired, and in more than one instance, two, or even more approximately parallel lines were found, within short distances of one another, evidently intended for a single boundary, each connecting with separate posts, designed to mark the same point. Over the larger part of the district, repeated forest fires have destroyed all traces of many of these lines, and the limiting posts, except where an occasional one happened to be located in a swamp, have been burnt, so that it is usually exceedingly difficult, and sometimes impossible, to locate these original boundaries.

Lines not always astronomical.

Careless surveying.

Destruction of boundaries by forest fires.

The general character of the country may, perhaps, be best described an that of an uneven or undulating rocky plain, with a gentle slope towards the south and southwest. In detail, the surface of the plain is far from uniform, consisting of a rapid succession of more or less parallel and disconnected rocky ridges, with a prevailing northeast and southwest trend, the intervening valleys being usually occupied by swamps, lakes or river courses. The average general elevation of the district as a whole, varies from 800 to 1,100 feet above the sea. The present topography has been the result of prolonged denudation and erosion, assisted to a considerable extent by subsequent glacial action, which removed the softer decomposed material from the higher levels, to be deposited elsewhere in the neighbouring valleys, or in areas considerably removed to the southwest. The scouring action of the vast glacier is everywhere apparent, in the smooth well-rounded hills, while in most cases, the exposed rock surfaces still preserve the glacial grooves and striæ. Although the country is exceedingly rocky and uneven, there are no very prominent hill features, the highest seldom attaining a greater altitude than 150 feet above the neighbouring valleys, while elevations of 25 to 100 feet are far more common. The highest land in the district comprises a strip varying in width from 3 to 5 miles, and extending in a northeasterly direction from Denison to Garson townships, a distance of over 30 miles. This is underlaid for the most part by the nickel-bearing and associated eruptives, although some areas of highly altered quartzites contribute to this unusual

General physical features of district.

Average elevation.

Glacial action.

No very pronounced hill features.

Location of highest land.

Character of underlying rock.

Location of highest hill.

elevation. One of the highest hills in this rocky belt is situated immediately south of the Elsie mine. Barometrical observation correlated with the known elevation at the intersection of the Elsie mine branch with the M. & N. S. railway, show this to have an altitude of 1,120 feet above the sea. Starting from Sudbury, which has an elevation of 850 feet, the Canadian Pacific railway ascends a series of steep grades for a distance of 3½ miles before the summit is reached, at an altitude of 992 feet; while an equal distance further, at Azilda station, this elevation is decreased to 881 feet above the sea. The Manitoulin and North Shore Railway Company, on the other hand, have built a portion of this road, a little over twelve miles in length, and have located it to Victoria mines and beyond, the line running through this hilly district for the whole distance. Starting from Sudbury, which as stated, has an elevation of 850 feet, the grade rises to 919 feet at Clarabelle junction, and further to 959 feet at Elsie junction. The summit is reached about 8 miles west of Sudbury, where the level of the rail is 986 feet, falling again to 965 fect above the sea, at the end of the profile 12·7 miles from Sudbury, close to the Gertrude mine. To the northwest of this hilly tract, the land becomes tolerably level, forming a plain with an average elevation of nearly 880 feet above the sea. This flat belt of country has an general width of about six miles, and stretches from the vicinity of Vermilion lake, in Fairbank township, almost to Wanapitei lake, a distance of over 30 miles. The whole of this area is evidently underlaid by the slates and felspathic sandstones coloured provisionally as of possible Cambrian age, but this rocky floor is largely concealed by a thick mantle of drift, through which protrude occasional low, rounded hummocks, which alone give evidence of the underlying material.

Elevations on Canadian Pacific railway.

Elevations on Manitoulin and North Shore Ry.

Flat belt of country between Vermilion and Wanapitei lakes.

Character of drift of the Chelmsford flat.

This drift is composed of a well stratified gray clay, unencumbered for the most part by boulders, and is seemingly well adapted for all purposes of agriculture. Roads have been opened, and large clearances made over most of this level district, the various barns and buildings erected, giving strong evidence of the prosperity of this farming community.

Another irregular flat.

To the south, and southeast of the hilly stretch already mentioned, a somewhat irregular shaped, and comparatively narrow valley, extends from the vicinity of the Worthington mine, almost to Wanapitei lake, where it connects to the north and west with the extensive plain just described. The continuity of this comparatively level tract of country is broken, at certain intervals, as for instance, near the crossing of the Whitefish river, but the whole flat may be considered as belonging to one valley, with a gentle though perceptible slope towards the southwest. In the township of McKim, this flat has an average general elevation of about 845 feet above the sea. From Sudbury, in a southwesterly direction, this comparatively level belt has been utilized in the location of the 'Sault Branch' of the Canadian Pacific railway, while, in addition, advantage has been taken of the even surface in erecting most of the buildings included in the towns of Sudbury and Copper Cliff. In the township of McKim, the surface of this flat is sometimes broken by small rocky hills, and the considerable areas, that are available, have been cleared, and are now under cultivation, with gratifying results, especially during those years when the roasting of the ores at the mines is not proceeding too briskly.

Flat in the township of McKim.

Farming good in places.

Throughout McKim, and the area to the southwest of this township the soil is a fine silty clay, well stratified; but to the northwest, in the township of Garson and beyond the limits of the Sudbury sheet, in the township of Falconbridge, this is replaced by a coarse yellow sand, with gravel in certain places, the whole forming a light and rather poor soil, although some portions of it are now being used for farming purposes.

Flat northeast of Sudbury.

To the east and southeast of Sudbury, the district is, for the most part, exceedingly rough and hilly, this area being characterized by the presence of quartzite, with large and irregular intrusive masses of norite and diorite, and only occasional limited flats are available for agriculture.

Rough area east and southeast of Sudbury.

Perhaps one of the most interesting physical features presented by this district, is the narrow valley formed by the weathering of the large diabase dyke, near the Murray mine. This dyke, which is about 150 feet wide at this point, and intruded through a mass of granite, has been decomposed and considerably eroded, leaving a valley the whole width of the dyke, with perpendicular walls of granite. This very conspicuous feature in the landscape has been used in locating the wagon road between Sudbury and Azilda (formerly Rayside).

Valleys caused by erosion of olivine-diabase dykes.

The influence exerted by the underlying rock on the general contour of the ground is everywhere well exemplified throughout this district. The harder igneous and quartzite rocks, owing to their greater resistance to processes of weathering and erosion, form the higher ridges, while the more fragile slates, sandstones and schists, make up most of the intervening lower ground, occupied chiefly by the river valleys, swamps and lake basins. The area covered by the main mass or belt of norite is likewise one of low relief, in contrast with the other igneous

Influence of underlying rocks on surface contour.

District not so abundantly supplied with lakes as other Archæan areas.

rocks with very small gently rounded hills, this variety of rock evidently offering no very effectual resistance to decomposition. The district, as a whole, is not as abundantly supplied with lakes as many other areas of similar Archæan rocks, but several fairly large and beautiful lakes occur, and nearly all are supplied with good clear water. The shores and islands of Ramsay or Lost lake, are occupied by the summer residences of many of the inhabitants of Sudbury, while its pure clear water is used to supply the large water tank, erected for the water works, on one of the rocky hills east of the town. The highest lake in the area is Garson lake, which is 923 feet above the sea; while the lowest is McCharles lake, an expansion of the Vermilion river, which has an altitude above the sea of 760 feet.

Elevations of lakes.

The drainage of the district by Wanapitei, Spanish and Vermilion rivers.

The drainage of this district is effected through three important and well known streams, the Wanapitei, Spanish and Vermilion rivers, the whole of the water eventually reaching Georgian bay and Lake Huron through these channels. The Vermilion river with its tributaries the Whitefish branch, Levey river, and Whitson and Fairbank creeks empties the water of nearly the whole of the area included in the two map sheets. The Vermilion river is itself a branch of the Spanish river, joining this stream near the boundary between Merritt and Foster townships, about 10 miles southeast of the corner of the Victoria mines map. A portion of the Spanish river, known as the 'Great Bend', crosses the corner of this map sheet, receiving in this distance, the whole of the drainage of the township of Drury, and the western part of Denison township. The branches of the Wanapitei river are limited to the eastern parts of Garson and Neelon townships.

District once covered by a dense forest.

Havoc wrought by fire.

The whole area was once covered with a dense forest, but repeated fires have destroyed nearly the whole of this original growth, and even the tall rampikes which often alone remained as the silent witnesses of the havoc wrought by the fire fiend, have themselves been gradually cut down to aid in kindling the heaps of roasted ore. Occasional small areas, as for instance, in the northern part of Garson, the western part of Snider and Creighton townships, are still covered by green bush, but the lumberman's axe is quickly clearing out all the valuable timber that remains, while the constant demand for cordwood as fuel for the roast heaps, will still further limit the forest area. Hardwood is scarce, and can only be found in valleys, chiefly in the vicinity of certain streams. Occasional dwarf oaks were noticed in some of the hollows between the higher ridges. The second growth usually consists of poplar and birch, these small trees being so closely packed together in some of the valleys as to form almost impenetrable thickets.

Character of forest growth.

The district, as a whole, cannot be said to be suitable for agriculture, and must rely for its ultimate importance on the development of its mineral resources. The proximity of the mines furnishes a good market, so that every flat is being utilized for purposes of farming.

District as a whole not suited to agriculture.

Geology.

The rocks of the Sudbury Mining District, arranged in the probable order of their geological age, may be stated as follows, in ascending order.

Geological subdivision of rocks.

1. *Lower Huronian.* No rocks of this age are at present known in the nickel bearing area, but this period is represented, in part, by the banded silicious magnetites and associated rocks of the townships of Hutton and Wissner.

General character of Lower Huronian.

2. *Upper Huronian.* (*A*) Diorites, hornblende-porphyrites and green schiste, (*B*) Conglomerates, greywackes and quartzites (*C*) norite and diorite (Worthington mine belt, and areas southeast of Evans mine and east of Sudbury).

Subdivisions of Upper Huronian.

3. *Laurentian.* Granite and diorite-gneiss near Wanapitei station.

Laurentian gneiss.

4. *Upper Huronian?* Tuffs, felspathic sandstones and slates classified provisionally on previous geological maps as of Cambrian age.

Character of Upper Huronian or Cambrian.

5. *Post Huronian.* *A.* Granites. *B.* Nickel bearing eruptive of the main belt (quartz-hypersthene-gabbro or norite, diorite, with their peculiar differentiation product, micropegmatite). *C.* Dykes of olivine diabase.

Post Huronian eruptive.

6. *Pleistocene.* Clays and sands.

Pleistocene.

The geological history of the nickel mining area proper, or that portion of the Sudbury district which is included in the accompanying map sheets, began in very ancient times, and most of the rocks now exposed are regarded as representative of what is known as the Huronian period, being thus the oldest with which geologists are at present familiar. The detailed examination and study of these rocks have furnished abundant evidence of the almost unexampled volcanic activity then prevailing, caused largely, no doubt, by the instability of the earth's crust at this early period of its history. These rocks are esssentially of pyroclastic origin, consisting mainly of tuffs of both acid and basic types, intimately associated with more or less altered basic eruptives, some of which still retain much of their original massive character, although by far the larger proportion have undergone such profound

General geological history of district.

Abundant evidence of unexampled volcanic activity.

deformation and metamorphism, that it is exceedingly difficult, if not impossible, even with the assistance of the microscope, to make any very definite or accurate statement in regard to their original composition and structure. Some of these eruptives are, however, probably of laccolitic origin, and intruded along the planes of bedding of the enclosing clastic rocks, while many of the porphyrites and obscurely amygdaloidal forms, doubtless represent surface flows of lava which have been very much altered and decomposed.

General types of eruptive rocks.

With the establishment of conditions of more stable equilibrium, came a time when the higher elevations were being subjected to the usual processes of degradation and erosion, with the transportation of the material thus detached to be deposited at the lower levels, forming the conglomerates, felspathic sandstones and quartzites, included in the above table as Upper Huronian. Even this period of comparative quiet was probably interrupted at intervals by a return of the volcanic activity, and some of the breccia-like material, and certain of the interbedded greywackes, may be the direct results of explosive action. Subsequent to the formation of these rocks, the huge bathyliths of granite and diorite-gneiss classified as Laurentian, and occurring in the vicinity of Wanapitei station, were intruded into the highest or quartzite member of the Upper Huronian. Later than these quartzites, and possibly also later than the Laurentian gneiss, certain mas es of norite and diorite, among which may be mentioned the belt on which the Worthington mine is located, were intruded. This Worthington mine band of norite, as may be seen by a reference to the map, extends across the southern part of the township of Denison, forming a conspicuous range of hills, a short distance south of the Canadian Pacific railway. The band of similar igneous material, which forms the high lands to the south of McCharles lake, is of the same age, as also its probable continuation, in the large belt of norite and diorite, which crosses the country to the southeast of the Evans mine. This same band of intrusive rock continues with unbroken continuity northeast, forming a considerable area of exceedingly rough country east of Sudbury, and north of the Canadian Pacific railway, besides covering a considerable portion of the northern and central parts of Neelon township.

First clastic rocks formed.

Volcanic interruptions.

Correlation in age of the various rock masses.

The age of the tuffs, felspathic sandstones and slates hitherto classified provisionally as of Cambrian age, and so coloured on all previous geological maps, is still a matter of considerable doubt, and much more detailed work and critical examination of the area, characterized by the presence of these rocks, will be necessary, before this can be

Age of so-called Cambrian, still a matter of doubt.

satisfactorily settled. They apparently form a synclinal basin, resting against the micropegmatite phase of the nickel bearing eruptive, and a study of several of the localities where the junction between these rocks is exposed, lends some support to the belief that the micropegmatite is intrusive through the tuff or breccia. On the other hand, it seems reasonable to suppose, that all of these rocks are very intimately associated in regard to their time and manner of genesis.

Age of granites.

The granites, usually referred to as 'younger', are decidedly so, in reference to the older diorites, porphyrites and green schists and a rock which may be called a breccia, formed by an exceedingly intricate intrusion of dykes and masses of granitic material through these basic rocks, covers considerable areas throughout this district; while even the main mass of the granite bathylith, frequently contains embedded fragments and masses of all sizes and shapes of these older greenstones.

Relative age of nickel bearing eruptive.

Anomalous behavior of norite.

The nickel bearing eruptive, which in its fresh condition is now referred to as a quartz-hypersthene-gabbro or norite, is decidedly later than, and intrusive through, the green schists and associated diorites. The relations between the so-called "younger" granite is much more complex and anomalous. For the most part, the nickel bearing eruptive, has cooled against the granite, as may be seen at the junction between these two rocks, on the west side of the large pit known as the No. 2 mine at Copper Cliff. Here, the norite is distinctly finer in grain at the immediate point of contact, this rock growing visibly coarser farther away from the line of junction. This cooling of the norite against the granite, and the production of a finer grained or chilled selvage, is especially well seen in the vicinity of the openings made by the Vivians on lot 9, concession VI., of McKim township. On the other hand, in some localities, certain dykes or apophyses of the granite, seem to penetrate the norite, as may be noticed along the line of junction to the northwest of No. 2 mine, at Copper Cliff; while the intrusive nature of the granite, and its apparently later age in relation to the norite, is quite marked to the north of Clarabelle lake, where the line of junction between the two rocks is well exposed for a considerable distance. Besides, near the Creighton mine, the granite becomes decidedly more basic in the vicinity of the norite, and a certain zone or belt is formed by the commingling of the material of both rocks, as a result of actual fusion. It has been suggested that the granite and norite may have been differentiates of the same magma, but a more reasonable explanation would seem to be that their periods of intrusion were so closely synchronous, that they overlapped

Intrusive nature of contact north of Clarabelle lake.

Character of contact near Creighton mine.

in their time of crystallization, and that the later secretions from the slower cooling granite magma, forced or ate their way into the norite in certain places.

Age of olivine diabase dykes

The olivine-diabase dykes cut through, and are, therefore, later than all the rocks with which they have been noticed in contact. Their mineralogical composition is essentially the same as the dykes of diabase-porphyrite in the Lake Superior district, which latter have been regarded as the channels by which the Keweenawan lavas reached the surface.

(2.) UPPER HURONIAN.

(A.) GREENSTONE SCHISTS.

Use of the term 'greenstone.'

It has been the general practice in previous reports of this and other Archæan areas, to employ the somewhat vague and indefinite term 'greenstone', the common field name for certain basic eruptive rocks, often more or less altered and deformed. In the present report, this term has been retained as the most appropriate and convenient designation for certain very ancient basic intrusives, presenting every possible phase of metamorphism and deformation. Under the general heading, 'greenstone schists,' are included several varieties of diorite, porphyrite, hornblende and chlorite schists. They are undoubtedly the oldest rocks with which we have at present any acquaintance in the district. Their usual occurrence in intimate association with the more massive and uniform norite, in addition to their general lithological appearance and behaviour, especially the more massive types, were the main reasons for grouping these rocks together, under the same colour designation, on all the earlier geological maps. In these first examinations, such rocks were regarded as the sheared and altered representatives of the more massive norites, the latter, by some fortunate circumstance or series of circumstances, having escaped this extreme of deformation and metamorphism. Later examinations have, however, revealed the fact, that in most cases, at least, these more or less foliated and schistose basic eruptive rocks, are distinctly older in age, and were upturned, faulted, folded and considerably metamorphosed, at some time prior to the intrusion of the nickel bearing eruptive proper. Careful and detailed work never fails to reveal the presence of a distinct line of separation between these two classes of igneous rocks, and the importance of accurately tracing out and mapping such a boundary, from an economic point of view, is especially emphasized, when it is remembered that all the deposits of nickel and copper ores, which are commercially valuable, are located either in the imme

Greenstones oldest rocks in area

Early misconceptions.

Greenstones not deformed portions of nickel bearing norite.

Mapping of lines of junction of norite very important diate neighbourhood, or at various points directly on the line of junction between the norite and the associated rocks.

Character and derivation of older diorites and greenstones.

The least altered representatives of these older diorites, or more massive varieties of the older greenstones, can with difficulty be distinguished from the prevailing type of diorite (altered norite), with which the nickel and copper deposits occur, and it is impossible to resist the conclusion that both rocks have originated from precisely similar types. Their difference in age, however, is quite evident from their field relations, and although both pyrrhotite and chalcopyrite occur in these earlier basic rocks, no deposits of economic importance have been found in association with them at any great distance from the line of junction with the younger norite or diorite.

No deposits of economic importance in older greenstones.

Colour of older greenstones.

Most of the hand specimens examined of the more massive types of these older rocks, are considerably finer grained than the neighbouring norite, and in contrast to this rock, are decidedly greenish rather than greyish or blackish in color. Most of the outcrops may be referred to as 'gabbro diorite', a name proposed by the late Prof. G. H. Williams, for a diorite which gives unmistakeable evidence in the hornblende, of its derivation from pyroxene, originally present. Some exposures exhibit the ophitic or interlacing structure characteristic of diabase, which is often discernible either to the unaided eye, or with the assistance of an ordinary pocket lens ,and the rock in which the structure is developed would be referred to as a uralitic diabase.

Gabbro-diorite or uralitic diabase the prevailing massive type.

Petrographical characters of older diorite.

Mineralogically, as represented by the thin sections, examined under the microscope, the rock is now composed essentially of plagioclase and hornblende, and no portion of the original pyroxene has yet been detected. The plagioclase, in all cases where the rock is sufficiently fresh for its identification, is labradorite, and in those specimens, which have suffered least from metamorphism, this mineral occasionally has a pale brownish tint, the colouring matter (presumably very finely disseminated ilmenite), being rather unevenly distributed through the various individuals, with cloud-like effect. Pressure and advancing decomposition, however, seem to quickly destroy or remove all traces of this colouring matter, so that, with few exceptions, the felspar is nearly, if not quite, colourless. As a rule, the plagioclase has undergone more or less advanced saussuritization, but some individuals are still sufficiently fresh to permit of their recognition by means of the extinction angles. All stages in this characteristic alteration of the basic plagioclase are represented in the specimens collected and examined, but this has been so fully described in previous publications, that only a brief mention is necessary in this connection. The first

Alteration of plagioclase.

step in the decomposition of the original felspar, consists in the development of minute scales of sericite, and fine needle-like forms of epidote and zoisite, in the midst of the plagioclase substance. Another, and very frequent form of development of these secondary minerals, consists of grape-like bunches of finely granular saussuritic material, chiefly zoisite or epidote, whose coalescence ultimately produces a single larger individual, or aggregate of several individuals of these minerals. One of the more advanced stages in this process of decomposition of the felspar, consists in the complete obliteration of the twinning lamellæ, and the replacement, either wholly or in part, of the plagioclase substance, by a brilliantly polarizing aggregate, made up chiefly of sericite, epidote and zoisite. In occasional instances, the place of the felspar is taken by a colourless or pale yellowish saussurite, which polarizes in dull bluish tints. This substance is usually so fine-grained that it cannot with certainty be resolved into its component minerals, even with the assistance of the higher powers of the microscope. Some of the coarser portions of this substance were examined rather critically, with the result that zoisite, sericite, a little calcite and a secondary plagioclase, possibly albite, were recognized as contributing to the aggregate. Still another form of alteration of the original felspar, and one often accompanying the more usual saussuritization, consists in the replacement of part of the original felspar by a fine interlocking mosaic of a clear, sharply extinguishing, secondary felspar (albite) and quartz.

General characters of saussuritie and its composing minerals.

Another form of alteration.

The hornblende, is as a rule, the usual deep green, strongly pleochroic, compact variety, occurring in long, imperfectly developed, prismatic forms. Occasionally the fibrous or actinolitic variety is represented, much paler in colour, and with less pronounced pleochroism. Many of the individuals of this mineral show the pale coloured, more or less non-pleochroic interiors, with deep coloured, much more compact, and strongly absorptive borders characteristic of uralite. Portions of occasional crystals show a brownish colour, but even these have a decided greenish tinge. Biotite is almost invariably present, and usually in large amount. It is of the usual deep brown colour, showing strong differences in the absorption of light when rotated between crossed nicols. It occurs in plates and scales, frequently embedded in, and sometimes forming intricate parallel intergrowths with the hornblende. It has often undergone considerable 'bleaching', and is then somewhat paler in colour than usual, besides showing brilliant chromatic polarization between crossed nicols. In spite of the elimination of a considerable portion of the iron, the pleochroism as stated is still very pronounced. It often contains irregular grains of

Microscopic character of bisilicate minerals.

Hornblende.

Biotite.

'Bleaching' of biotite.

magnetite. Both the hornblende and biotite show frequent decomposition to chlorite. 'Pleochroic halos', surrounding embedded small grains or crystals, chiefly of sphene, are frequent in both the hornblende and biotite, as well as in the chlorite derived from them. Comparatively large and sharply defined crystals of epidote and zoisite occur, some of which may be of primary origin, although by far the larger proportion are undoubtedly the secondary products of decomposition. Quartz is almost invariably present, occasionally forming the characteristic granophyric intergrowth with the felspar. In most cases it is not of secondary origin, but an integral part of the same magma out of which the other minerals have been formed. It was as usual the last mineral to form, filling up the irregular interspaces left by the crystallization of the other constituents. Ilmenite and highly titaniferous magnetite are the prevailing iron ores, and these are present often in comparatively large amount. Most of the individuals are surrounded by opaque grayish leucoxene, or the more normal sphene, resulting from the alteration of the titaniferous iron ore. Apatite is usually present in small amount, occurring in the characteristic long, acicular, prismatic forms, which pierce all the other constituents of the rock. Pyrrhotite, chalcopyrite and pyrite, frequently occur disseminated through the rock, and under the microscope are seen to form curious irregular skeleton or sponge-like masses, intimately associated with, and frequently embedded in the coloured constituents.

Decomposition of hornblende and biotite.

Epidote and zoisite.

Quartz, a primary constituent.

Ilmenite and titaniferous magnetite.

Apatite.

Sulphides.

These diorites occur in all stages of decomposition, while still retaining much of their original massive character. A type illustrative of perhaps the extreme of this alteration is well represented by a hand specimen obtained from the tunnel in 'Lake Hill', lot 8, con. IV., of Denison. This rock is a fine-grained, comparatively light greenish-gray, diabasic rock, with occasional fine disseminations of pyrrhotite and chalcopyrite. The thin section shows that all of the hornblende and part of the biotite have been altered into green chlorite, which retains much of the strong pleochroism characteristic of the original minerals from which it has been derived. The ilmenite has been almost wholly converted to sphene, which occurs in irregular grains and crystals. Calcite is very abundant, and portions of the slide are made up of a rather coarse mosaic of quartz and calcite, with a smaller proportion of chlorite. As a rule, these old diorites are comparatively uniform in grain, but porphyritic varieties occur, and a good example of this phase, was collected from certain small rounded hummocks, on the west side of the upper or new roast yard of the Victoria mines, (N. $\frac{1}{2}$ lot 8, Con. III, Denison). The hand specimen, shows, a comparatively coarse-grained rock, made up of indefinite or irregular phenocrysts of

Altered diorite.

Decomposed diabasic rock from "Lake Hill" Denison.

Mineralogical composition.

Porphyritic diorite of roast yard at Victoria mine.

Mineralogical composition.

dark green, almost black hornblende, embedded in a proportionately smaller amount of a comparatively fine-grained matrix, which is rather paler in colour. The microscope shows the rock to be a porphyritic diorite, made up very largely of a green, feebly pleochroic hornblende. Much of the hornblende is compact, but in the finer-grained portions of the rock, as well as in the terminations of the larger crystals, the mineral shows a marked tendency to assume the actinolite habit. The interspaces between the larger porphyritic individuals are made up of saussuritized plagioclase, actinolite and ilmenite, the latter mineral in various stages of alteration to leucoxene. Occasional small scales of biotite may be noticed embedded in the hornblende.

Hornblende-porphyrite from Murray and Elsie mines.

Another closely related rock is that which is usually referred to as 'hornblende-porphyrite.' This type of rock is perhaps best illustrated by outcrops occurring to the southeast of the Elsie mine, while the steep and prominent hill southeast of the office at the Murray mine, is almost wholly made up of this material. The groundmass is much finer in grain than in the porphyritic diorite just described, but the phenocrysts are usually considerably larger and more conspicuous, their deep green, almost black colour, with glistening cleavage planes, contrasting well with the fine-grained and lighter coloured matrix made up largely of hypersthene with some felspar. Still another closely related form, and one which may be included in the general class of the older and more massive greenstones, may perhaps be best described as a 'diorite-porphyrite'. The best examples of this type of rock were obtained from exposures outcropping a little north of the boundary between Graham and Creighton townships, on lot 2, con. I of Creighton township. The hand specimen shows a dark-green, rather schistose, dioritic rock, with ill-defined phenocrysts of plagioclase, some portions of which are of a paler yellowish-green colour, while other parts of the same crystal are reddish. Under the microscope, the thin section shows that these large irregular phenocrysts are labradorite, which have undergone more or less advanced alteration to saussurite or huronite, with the development of zoisite, epidote and sericite. The reddish portions of the crystals are comparatively unaltered and still show the twinning lamellæ. The finer interstitial matter is made up essentially of green hornblende and plagioclase. Some of these individuals show the pale interiors and comparatively dark-green borders usually considered as characteristic of uralite. Most of the plagioclase has undergone more or less advanced saussuritization. The iron ore present is mainly, at least, ilmenite, for it may be seen undergoing alteration to leucoxene. A little quartz is present, and also an occasional scale of biotite.

Diorite-porphyrite between Gertrude and Creighton mines.

Mineralogical composition of diorite-porphyrite.

Formation of different types of greenstone schists.

Very frequently these more massive types pass into foliated schistose varieties, the structures being the direct result of pressure and stretching, and all gradations may frequently be observed in the same rock exposure, from the massive gabbro-diorite, through diorite schist, hornblende schist or amphibolite, to actinolite and chlorite schist. The prevailing type of hornblende schist or amphibolite, is a dark-green to almost black, usually glistening and very fissile rock. It is made up largely of slender prisms of the common green hornblende, usually compact and strongly pleochroic, but sometimes actinolitic, a varying but usually small amount of plagioclase and quartz occupying interspaces between the rudely parallel individuals. In the less altered varieties the original plagioclase still remains, although usually more or less saussuritized, but some specimens examined are seen to have undergone more or less complete recrystallization, with the formation of an interlocking mosaic of water-clear, usually unstriated plagioclase (albite ?) and quartz. Biotite is almost invariably present, and the iron ore is sometimes ilmenite, or highly titaniferous magnetite, the grains of this mineral being bordered with sphene. In other instances, the iron ore is simply magnetite, showing no traces of alteration and this mineral is often present in large quantity. Pyrrhotite, chalcopyrite and pyrite, are sometimes disseminated through the rock in small grains, and in the vicinity of the ore bodies, these sulphides are often abundantly present in this type of rock. Some exposures of these rocks are made up almost entirely of hornblende. The thin section of a specimen, secured from Cryderman mine, (lot 5, ccn. III., Garson) showed this rock to be made up of hornblende individuals closely compacted together, with no intervening felspar or quartz. Magnetite is abundant, while pyrrhotite and chalcopyrite are thickly disseminated through the rock. Some phases of these hornblende schists are sometimes so badly decomposed that only occasional cores of the hornblende crystals have survived, the remainder having been converted into chlorite. The plagioclase and quartz present in these rocks, are often indistinguishable from one another, the former being the clear, often unstriated variety (albite), so characteristic of these recrystallized eruptives. Biotite is present in much smaller amount, and has likewise contributed by its alteration to the formation of the abundant chlorite. Epidote and calcite are also present in comparatively large amount, as secondary products of decomposition. Magnetite is plentiful, and much of it is undoubtedly of secondary origin. These rocks are usually much paler in colour than the prevailing and less decomposed varieties of amphibolite.

Mineralogical composition of amphibolite.

Amphibolite from Cryderman mine.

Decomposition of amphibolite.

'Augen' amphibolite.

In certain localities these hornblende schists were noticed to contain numerous small, irregularly oval, light-coloured patches or 'augen', sometimes made up almost entirely of plagioclase, or this mineral in association with an equal or even greater quantity of quartz, while in certain instances, quartz alone is present. These are of various sizes and shapes, but they are usually less than a quarter of an inch in diameter, and most of them are about the size of an ordinary pea. In certain instances, some of the larger of these areas seemed to be made up of a single imperfect phenocryst of plagioclase, but a study of the slides usually shows, a mosaic made of several distinct interlocking grains of this mineral, together with a varying amount of quartz. The rock, at first sight, suggests, an amygdaloid, with the amygdules or vesicles filled with this quartzo-felspathic material, but a more reasonable explanation suggests their probable origin as small, more or less continuous veins, of pegmatite which have become thus deformed and separated as a result of stretching. The structure is of rather frequent occurrence and characteristic of comparatively large areas of the amphibolite. Similar rocks have been noticed by Dr. Coleman as occurring in the vicinity of the Frood mine, while in the central part of the township of Graham, the writer has collected several specimens from the N. ½ lot 8, con. III., and the N. ½ lot 1, con. IV., of this township. The matrix in which these small eye-like forms are developed, shows a fine-grained hornblende schist made up, in great part, of compact, dark-green, strongly pleochroic hornblende, together with a little biotite. In the specimen from the N. ½ lot 1, con. IV., of Graham, the quartz and felspar of many of the 'augen' contain small scattered individuals of hornblende, zoisite and biotite.

Origin of 'Augen.'

Augen amphibolite from Frood mine and Graham township.

Biotite schist from Denison.

Another type of rock, which was noticed at two widely separated localities, intimately associated with these amphibolites, is a dark-gray, almost black, faintly glistening schistose rock. The thin section of a specimen obtained near the openings on lot 12, con. IV., of Denison, shows a fine-grained aggregate of pale-coloured or 'bleached' biotite, with a much smaller amount of plagioclase. Small grains of sphene are abundant, and also irregular fragments of calcite.

Biotite schist from Graham.

Another variety of the same rock is represented by a specimen obtained near the Century Copper mine, on the N. ½ lot 4, con. IV., of Graham. It contains frequent disseminations of pyrrhotite, pyrite and chalcopyrite, and in addition to the plagioclase, contains a considerable amount of quartz. The biotite, which is in fairly large plates, is 'bleached' with frequent pleochroic halos, surrounding certain of the smaller inclusions, which are abundant, and include sphene, epidote and zoisite.

Garnetiferous amphibolite from Vermilion mine.

Occasionally these amphibolites contain garnet, which is sometimes abundant, and often in large, ill-defined or rounded crystals. The most striking example of such a rock is, doubtless, that occurring in the vicinity of the Vermilion mine, (lots 5 and 6, con. IV., of Denison). The matrix shows the prevailing fine-grained, dark-green schist, in which rounded crystals of reddish garnet, sometimes two inches in diameter, are developed. The matrix is made up principally of hornblende and quartz. The garnet is quite normal, but is much cracked and slightly seamed with green chlorite, which has resulted from its incipient alteration. It was also noticed to contain inclusions of magnetite and quartz.

Microscopical determination of minerals.

Origin of greenstones.

There can be little doubt in regard to the origin of most of these older greenstones, that they represent greatly decomposed, sheared, and, at times, completely recrystallized, basic eruptives, but there is still considerable doubt regarding the exact conditions attending the genesis of certain other types of rocks, which are intimately associated with, and usually included in these greenstones. Some of these show, though somewhat indistinctly, the ellipsoidal and amygdaloidal structures, characteristic of lava flows, while others, again, are almost certainly of a pyroclastic nature, representing consolidated beds of volcanic ashes and fine agglomerates, but all of these have been so greatly squeezed and stretched that their precise identification is extremely difficult, if not impossible. Some portions of the sedimentary rocks, chiefly quartzites and greywackes, are included in these areas of greenstones. In some instances, these clastic rocks, which have been thus caught up in the greenstone, are sufficiently large to permit of being separated on the map, but, for the most part, they are comparatively small, and have been included under the same colour as the greenstone. All of these clastic rocks are greatly metamorphosed. The tuffs or greywackes are now made up chiefly of clear felspar, with a smaller proportion of quartz, the former mineral being largely altered to sericite; biotite, chlorite and magnetite or ilmenite, are the most abundant minerals represented. Often recrystallization has been so advanced that no traces of their detrital origin remain. The quartzites are of the usual felspathic variety, the component grains only occasionally revealing traces of water action, the structure, for the most part, being eminently interlocking.

Deformed eruptives.

Squeezed lava flows.

Altered volcanic ash rocks.

Altered clastic rocks included with greenstone.

(2.) UPPER HURONIAN.

B. CONGLOMERATES, FELSPATHIC SANDSTONES AND QUARTZITES.

General characters of rocks of Upper Huronian.

Although a large proportion of the rocks included as Huronian, in the Sudbury District, are the direct result of igneous action, considerable areas are underlaid by others of undoubtedly sedimentary origin. While, however, the various types of these rocks have been studied in considerable detail, so that their precise mineralogical composition is well understood, their stratigraphical position has not been determined as satisfactorily as might be desired, as only a comparatively limited time could be spared from the work of examining and delimiting the more important eruptives, directly associated with the ore bodies. The geological succession therefore, advocated in this report, is not based on an extended or critical study of the field relations of these rocks, and much more exhaustive work will be necessary before a final and authoritative utterance is possible on this point. Some difficulties which presented themselves during even the preliminary investigations undertaken by the writer, may be mentioned briefly. In the first place all the rocks of the district have been greatly disturbed, so that, the originally horizontal strata are now tilted at very high angles, in some instances, having assumed a vertical attitude, and occasionally, have even been overturned as a result of the mechanical stresses, to which they have been subjected. In some cases, and over extended areas, the rocks have been so metamorphosed, that the planes of original sedimentation are more or less completely masked, or even destroyed altogether, thus rendering it very difficult, if not impossible to interpret the true structure or succession. In addition, the situation is further complicated, and a satisfactory explanation delayed, by reason of the frequent development of certain secondary structures due to intense and prolonged pressure and stretching. The foliated, schistose or slaty structures, thus induced, are frequently mistaken for bedding planes, although usually forming considerable angles with them. Besides the continuity of the areas of the clastic rocks is frequently broken by the intrusion of irregular masses of igneous material which not only greatly disturbed and obscured the original order of deposition, but divide these sedimentaries into a number of separate basins, whose satisfactory correlation can only be unravelled by much more detailed study than the present opportunity afforded the writer. At this stage, therefore, the succession favoured in this report, is not offered without a certain degree of hesitation, although it is without doubt, a much more complete and satisfactory classification than any which has yet been attempted. With the exception of one or two minor points, it differs in no essential particular from the scheme offered by Dr. Coleman in his last report, (1) and we both agree, in advancing the opinion, that the intrusion of the nickel bearing norite, took place at a much later date, than formerly supposed.

Stratigraphical position not satisfactorily determined.

Difficulties of determining true succession.

Rocks greatly disturbed and altered.

Schistose structures mistaken for bedding.

Succession interrupted and complicated by intrusive masses.

Present scheme offered with some hesitation but essentially the same as Dr. Coleman's.

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(1). Ann. Rep. Bur. of Mines, Ont. 1903, p. 298.

It is confidently expected, however, that Dr, Coleman, as a result of the later work he is now conducting in the district, will decide many of the questions which are still a matter of opinion and conjecture, and the appearance of his monograph is accordingly awaited, with the expectation that this question, of succession especially, will receive full and satisfactory treatment.

Expected Dr. Coleman's later work will determine true succession

The oldest clastic rocks exposed in the vicinity cf Sudbury, are certain felspathic sandstones or greywackes, frequently interbedded with, and passing by insensible gradations, into felspathic quartzites or arkoses, the latter, for the most part, being the later rocks, and usually forming the summit of the series. These rocks are evidently closely related, the main point of difference noticed, consisting in the relatively coarse grain and large amount of quartz in the quartzites, with less of the finer-grained interstitial material, this being made up, for the most part, of the lighter coloured decomposition product sericite, while in the greywacke, the texture is finer, and felspar, not quartz is the predominant constituent. Chlorite, with innumerable fine, disseminated particles of opaque matter, gives the prevailing dark colour to the rock. The quartzites, for the most part, occur in thick, massive beds, which are very uniform in mineralogical composition, while the greywackes are much more distinctly and evenly stratified, and certain shales and slates exposed in the district, are evidently thinly bedded varieties of this rock. All intermediate stages, both in composition and structure, may be noticed between these two types of rock, which at the two extremes, are quite distinct and recognizable. Comparatively large areas are characterized by the prevalence of one or other of these rocks.

Oldest clastic rocks of Sudbury.

Mineralogical composition of greywacke

Transition between greywacke and quartzite.

Some of the greywackes are evidently of the nature of muddy sediments, deposited in water, as a result of ordinary conditions of degradation and deposition, but tuffs constitute, by far, the larger part, representing the consolidation of what was originally volcanic ashes, being one of the results of the explosive action to which is due the presence, at the surface, of the great belts of greenstone. These have, in most cases, been sorted and re-arranged by the action of water, but, in other instances, little or no trace of rounding action can be detected in the component grains, even in those types which have suffered little or no alteration. These rocks are usually of a dark-gray, purplish-brown, or greenish-gray colour. They are often evenly and very distinctly banded, in varying shades of gray. Jointing is frequent and also slaty cleavage. They are often faulted and shattered, and in the vicinity of the various greenstone masses, are penetrated and altered by irregular tongues and masses of the basic igneous material. They are frequently

Origin of greywacke.

Microscopic structures. of greywacke.

Porphyritic greywacke or 'rice rock.'

porphyritic, and usually the phenocrysts are small, very thickly disseminated, and of a very pale-grayish or whitish colour. For this reason, the rock has been referred to, in the field, as 'rice rock.' These phenocrysts were probably andalusite or staurolite, but the skeleton-forms are now occupied by a confused aggregate of minute sericite scales and quartz. Other exposures show small yellowish-brown spots made up of rutile, while others again, exhibit irregular phenocrysts of hornblende, now wholly replaced by chlorite. Thin sections, examined under the microscope, reveal a rock which has undergone rather extensive decomposition. It is usually made up very largely of felspar, with a smaller proportion of quartz, in small, angular or slightly rounded fragments. These are surrounded by a net-work of sericite and chlorite scales, together with a considerable amount of opaque iron ore. The larger individuals, at least, have evidently been ilmenite, but are now almost completely altered to leucoxene. The darker bands are made up of more thickly disseminated, dust-like particles of iron ore, much of which at least, is ilmenite. In the vicinity of the various eruptive masses, as well as in those masses which have been caught up in the greenstone, these rocks are very much altered, the various types having been described as mica schists, felsites and phyllites. The rocks referred to as quartzites are massive, though usually distinctly stratified, of a pale-gray reddish, yellowish-gray, or greenish-gray colour. They are intimately associated and often interbedded with the tuffs or greywackes, so that it is frequently impossible to separate the two for purposes of mapping. Under the microscope the thin section exhibits a rock made up chiefly of quartz, with a somewhat smaller proportion of felspar, most of which is unstriated, and therefore presumably orthoclase. Occasional grains of microcline were noticed, showing the various stages in the development of the characteristic fine, cross-hatched, twinning structure. Much of the felspar is decomposed into a hydrous form of muscovite (sericite), occurring in irregular, pale-yellowish or colourless scales and plates, which together with fragments of undecomposed felspar, make up a groundmass, in which the larger individuals of quartz, and more rarely of felspar, are embedded.

Phenocrysts of andalusite staurolite and hornblende.

Composition of greywacke.

Alteration of greywacke.

Quartzites

Mineralogical composition of quartzite.

Microscopical structure.

The structure of the rock is for the most part interlocking, but some specimens show distinctly clastic structure, while, in most, the resemblance to well authenticated, recrystallized clastics is such as can hardly be mistaken.

Altered quartzite band northwest of Sudbury.

A little over a mile northwest of Sudbury, the Canadian Pacific railway crosses a belt of very highly altered felspathic quartzite, the outcrops of this rock, forming a series of comparatively high and conspicuous ridges. This band averages about half a mile in width, and extends with unbroken continuity, from the vicinity of the Frood mine to Copper Cliff. Here, denudation has removed a considerable portion of these rocks, leaving only small areas such as that which outcrops immediately north of the old Copper Cliff mine. These rocks are again exposed to the west of the Ontario Smelting Works at Copper Cliff forming the high ridges, which with some minor breaks, extend in a southeasterly direction, a little beyond the boundary between Waters and Graham townships. Areas of very similar rocks are shown on the map, as occurring in the township of Denison, the largest mass covering a considerable tract north of the Vermilion mine. The microscopical examination of most of the thin sections, representative of this rock, throws little or no light on its origin, and the exposures might very readily be mapped as belonging to a biotite or hornblende granite, while the presence of a breccia of autoclastic character at the junction between this and the greywackes to the southeast, might easily be interpreted as indicating the intrusion of a granitic rock through the greywacke.

Altered quartzite in Denison, Graham and Waters townships.

Autoclastic rocks.

These small, usually parallel, and seemingly dyke-like forms of quartzo-felspathic material, are in reality thin beds of arkose material, which, originally continuous, have been drawn out, broken and separated during the processes of stretching, while the enclosing rocks, having yielded more readily to deformation, give no evidence of autoclastic action. This quartzite is frequently 'blotched' in the vicinity of the railway line, the spots or blotches of a pale-reddish or pinkish colour, being embedded in a network of grayish material, without however, any sharp or well-defined boundary between these two portions of the rock. It is made up principally of quartz, felspar, biotite, muscovite and sometimes hornblende, the last mentioned mineral being especially conspicuous in those exposures of the rock crossed by the railway and wagon road to Azilda. This mineral occurs usually in long, slender prisms, of a dark green colour, disposed at various angles to one another, and very evidently the product of secondary action.

'Blotched' quartzite northwest of Sudbury.

The component minerals possess the irregular, interlocking outlines, with usually no suggestion of the rounding action of water and at first sight, has every resemblance to a granite or gneiss. An examination of the field occurrences of this rock is, however, much more satisfactory than that of the thin section under the microscope. At times, a series of beds can be traced out, differing considerably in composition and texture, the whole occurring in the form of a synclinal basin, resting upon the greywackes. This quartzite represents the most advanced

Mineralogical composition of altered quartzite.

'Regenerated granite.'

Stratigraphical succession.

type of a recrystallized arkose for which the term 'regenerated granite' has been proposed (¹). In the Huronian, there are no very large areas of conglomerate, and the exact position of these rocks is still a matter of doubt, but it is hoped that future investigation will, at an early date, enable a precise statement of their stratigraphical position to be made. From the investigations undertaken by the writer, these conglomerates would appear to lie at the base of a series, which passing upwards into darker coloured felpathic sandstones or greywackes, are in turn overlaid by felspathic quartzites or arkoses which cover the larger portion of the southeastern part of the Sudbury map.

Character of conglomerates

Mineralogical composition of conglomerates.

Ramsay lake conglomerate.

Conglomerate in Denison.

Such rocks are, as a rule, of a dark-gray colour, with disseminated, angular, subangular, or rounded fragments, chiefly of quartz, granite, diorite, etc. Thin sections exhibit a rock made up of fragments, chiefly of quartz, but also of orthoclase, plagioclase and microperthite. The most abundant composite fragments are granitite, composed mainly of microperthite and quartz, together with a little biotite. All of the larger individuals are embedded in a matrix, made up of much finer pieces of quartz and felspar, together with biotite, sericite and a pale-green chlorite. Occasional grains of pyrite and also some of ilmenite occur. Excellent exposures of the last mentioned conglomerate may be seen along the line of the Canadian Pacific railway, immediately east of Sudbury, and in the vicinity of the north shore of Ramsay lake. As usual, these conglomerates are extremely local in their development, covering no very large extent of country, and the area to the east of Sudbury is, by far, the largest covered by such coarse, detrital rocks. Exposures of a very similar rock occur on lot 7, con. I., of the township of Denison, to the south of a small lake, the conglomerate at this place underlying the quartzite.

Conglomerate near Stobie mine.

Probable unconformity in Huronian.

Dr. Coleman mentions that, 'the most typical conglomerate in the region, however, extends as a much broken band from northeast to southwest, near Stobie mine, showing crowded pebbles and small boulders of more than half a dozen kinds, including granite, quartzite and several sorts of green schist, as well as greenstone.' (²) The occurrence of these conglomerates and the character of their pebbles, indicate a probable lack of conformity in the Huronian, and it is quite possible that there is a lower and an upper series, the former made up of greenstones, schists, greywackes and highly altered quartzites (regenerated granites), overlaid unconformably by the conglomerates just mentioned, together with the overlying greywackes and felspathic sandstones

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(1.) Quart. Journ. Geol. Lon. Vol. LIII (1897) p. 44.

(2) Ann. Rep. Bur. of Mines Ont., 1903, pp. 239 and 290.

exposed in the southern part of the Victoria mines map, and the south-eastern part of the Sudbury map. Besides these coarse detrital rocks, which are evidently consolidated shore deposits, there are certain pseudo-conglomerates or autoclastic rocks, formed, as already stated, as a result of pressure and deformation. These 'crush' conglomerates are especially abundant where the harder and more brittle quartzites come in contact with the schistose greywackes. Certain portions of the green schists, penetrated by granitic material, have likewise become autoclastic, through the stretching and rolling out of the rocks, while large portions of the greywackes themselves, have been broken, the fragments separated and recemented together, by similar, though somewhat coarser material.

Pseudo-conglometates or autoclastic rocks.

Autoclastic greenstone and granite breccia.

(2.) UPPER HURONIAN ?

(O.) OLDER ? NORITES AND DIORITES.

Certain areas of gabbro and norite, with their derivative diorite, occur, which have no direct or visible connection with the main mass of the nickel bearing norite. Most of these intrusive masses exhibit certain peculiarities of composition and structure, which all seem to possess in common, and by means of which, they may usually be distinguished from the ordinary norite. The possession of these characteristics, as well as their prevailingly greater alteration, suggests a probable difference in age, and the position assigned to them in the table of the geological formations exposed in this district, is believed to be a very close approximation to the truth. Most of these masses, at least, are distinctly younger than any of the clastic rocks with which they come in contact, as they pierce and alter the highest beds of the quartzites, which occur in the region covered by the southern and south-eastern portions of both the accompanying map sheets. Their age, with regard to the granite or main mass of norite, is not known, as they nowhere occur in conjunction with these rocks. They are, however, older than the olivine-diabase, for dykes of this latest rock in the area, are seen to cut them in many places.

Peculiarties of older norite and diorite.

Older norites are younger than clastic rocks.

Relation with main mass of norite uncertain.

With the exception of the Worthington mine, no large or economically valuable deposits of nickel or copper have been found in connection with them, although the Mitchener and Totten mines, situated in the township of Drury, were opened on masses of these minerals which were directly connected with the Worthington mine intrusive. Other deposits of these sulphides are known to occur at several points, as for instance on lot 12 con. III., of Neelon township, where the pyrrhotite was found to contain 3.10 per cent of nickel, and on the north half of lot 4, con. VI., of Neelon township, but, so

Worthington mine only large deposit of older norite.

Other deposits.

far as known, none of these are of sufficient dimensions to form working mines under present conditions.

Outline of band of older norite.

One of these belts of norite starts in the township of Drury, to the south of the Canadian Pacific railway, and extends across the southern part of the township of Denison, ending a short distance east of the Vermilion river. The small areas shown on the map, as occurring on lot 12, con. II and III., of Denison, are of the same rock. Another band forms the high land between Trout, Clear and Whitefish lakes on the southeast, and McCharles and Simon lakes on the northwest. The highest portion of the ridge rises 220 feet above McCharles lake. The probable continuation of this band forms the higher hills northwest of Kelley lake, and with some minor breaks, the ridges formed by the outcropping of these hard rocks, extends to the eastern end of Ramsay lake. To the north of the Canadian Pacific railway, and to the east of the town of Sudbury, the rock forms a series of exceedingly rugged and comparatively high hills, the highest of which rises over 1000 feet above the sea. This mass of norite and diorite covers an area of about four square miles in this part of McKim and Neelon townships, sending off a long narrow arm, which crosses the sixth concession of the township of Neelon. The large irregular mass of similar igneous material, occurring in the eastern part of Neelon, and shown on the map as covering portions of the third, fourth and fifth concessions, is known to be directly connected with the same mass. With the exception of the smaller separated masses, with which the Frood and Stobie mines are connected, and which undoubtedly belong to the main mass of the norite, all of the smaller areas of massive, basic, igneous rocks, shown on the map, are made up of this or a closely related type of rock. In addition to these, considerable areas of massive diorite occur in intimate association with, and probably intrusive through, the older greenstones and tuffs, which make up the larger portion of the area covered by the third and fourth concessions of Denison. These rocks are quite distinct from that which forms the main mass of norite, and are seemingly more closely related to this older norite intrusive. Similar areas of diorite rocks occur in the belt of older hornblende and tufaceous rocks, which crosses the third and fourth concessions of Graham, to the south of the granite mass. Deposits of pyrrhotite, chalcopyrite, pyrite and cobaltiferous arsenopyrite are known to occur in connection with these rocks, but they are not at present of economic importance.

Older norite east of Sudbury.

Older norite in Neelon township.

Smaller areas of older norite.

Older norite in Denison.

Older norite in Graham.

Field character of older norite.

In the field, outcrops of these older norites, are pale-greenish, in contrast to the dark-grayish or black tones of the main mass of norite. They are, as a rule, finer in grain, eminently diabasic in texture and frequently show considerable masses of diorite pegmatite, or malchite, in this last respect, differing from the ordinary norite, which is remarkably uniform in grain over the whole area. Under the microscope, they contain less quartz, and the hornblende is always actinolite, and not the compact variety common in the diorite derived from the norite of the main mass.

Fresh representatives of this apparently older norite are comparatively rare, and the writer's specimens, selected with every care, at widely separated localities, contain only two specimens in which the pyroxenes are sufficiently fresh to permit of their identification, and even in the slides from these specimens, by far the greater portion of the original ferromagnesian constituents, are represented by the usual secondary serpentine and actinolite.

Fresh representatives of older norites very rare.

One of the hand specimens of the least altered phase of the diorite, collected near the eastern extremity of the band of greenstone, between Whitefish and Simon lakes, is a pale greenish, medium-textured, massive greenstone, with little or no evidence of having been subjected to dynamic metamorphism.

Fresh norite from between Whitefish and Simon lakes.

The thin section shows a hypersthene-gabbro or norite, the greater portion of which has undergone advanced chemical alteration or decomposition. For the most part it is now made up of plagioclase and a serpentine closely related, if not identical with bastite. The latter mineral is very evidently secondary, and occupies very approximately the same position as the original bisilicate material, from whose alteration it has resulted. Occasionally, limited areas show the original pyroxenic minerals, in various stages of the bastitic alteration. A faintly pleochroic hypersthene or enstatite and diallage are both present, and some of the individuals or grains of these minerals are, with difficulty, distinguishable from one another. Both minerals are very nearly colourless, but the double refraction of the hypersthene is weak, while the diallage, on the contrary, shows brilliant chromatic polarization. Both pyroxenes show a faint, though distinct pleochroism, that possessed by the hypersthene being more decided. The index of refraction of the hypersthene is somewhat higher than that of the diallage, while the latter mineral shows frequent polysynthetic twinning. Both pyroxenes, however, decompose to the smea pale greenish, usually fibrous, but occasionally scaly bastite, often exhibiting brilliant polarization colours. In places, this bastite is being converted into a pale greenish, feebly pleochroic, fibrous hornblende or actinolite, this uralitization being especially pronounced in the vicinity of the margins of the individuals. These bastitic areas contain

Microscopical character of older norite.

Mineralogical composition.

Enstatite and diallage.

Decomposition of pyroxenes.

Bastite.

very numerous, small, irregular scales and plates of a pale brownish, apparently secondary biotite, and, in places, are crowded with small grains of secondary magnetite. The plagioclase, which judging from the extinction angles is labradorite, has a marked poikilitic development, this mineral extinguishing simultaneously over large areas, which in the thin section, are separated either partially or wholly by intervening bisilicate material. This poikilitic effect is likewise noticeable in the hand specimen, owing to the uniform reflection of light from the plagioclase individuals. Comparatively large, irregular grains of magnetite probably titaniferous, are also distributed through the rock, while quartz occurs, filling up occasional interspaces between the tabular forms of felspar.

Poikilitic plagioclase.

Titaniferous magnetite.

Fresh norite from Neelon.

Another specimen, representing a very fresh variety of this rock, was obtained from a small hill, west of a lumber road, on lot 11, con. V., of Neelon. Dr. Coleman mentions the fact that a specimen of this rock from the hill top east of the town of Sudbury, is 'a typical norite made up essentially of faintly pleochroic enstatite or hypersthene and plagioclase, the latter somewhat lath-shaped.' (¹)

Norite east of Sudbury.

Mineralogical composition of older norite southeast of Evanc mine.

A thin section from a specimen obtained from the large mass of this rock, occurring to the southeast of the Evans mine, shows a greatly altered variety of this norite. The original pyroxene minerals are wholly converted into an aggregate of pale greenish, brilliantly polarizing scales and fibres of serpentine, this, in turn, being converted, in certain instances, to actinolite. Pale coloured biotite is abundant. A small amount of greenish-brown, compact hornblende is also present. The plagioclase, with the pale brownish tints so common in these rocks, occurs in rather broad, lath-shaped or tabular, well-twinned crystals, which are, as a rule, quite fresh. Quartz is not very abundant, and some grains are intergrown with plagioclase, forming the characteristic granophyre. The iron ore is ilmenite, with borders of sphene. Apatite is abundant, in the usual slender, prismatic forms.

Description of altered norite from N½ lot 10, con. V., Neelon.

Another thin section, taken from a specimen obtained on the north half of lot 10, con. V., of Neelon, is still more decomposed, the pyroxene being replaced by a very pale yellowish-green serpentine and actinolite. All the intermediate stages in the conversion of serpentine to actinolite may be studied. Much of the felspar is quite fresh and clear, with a pale brownish colour, but the areas of this mineral have been invaded, to a considerable extent, by small fibres and crystals of actinolite. A little compact, brownish hornblende is also present. A large

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(1) Ann. Rep. Bur. of Mines, Ont. 1903, p. 296.

amount of zoisite occurs as a secondary product of decomposition. Ilmenite, largely altered to sphene, and occasional grains of pyrrhotite and chalcopyrite are also present, while quartz occasionally occupies the irregular interspaces between the plagioclase laths. Another specimen, from the north half of lot 4, con. VI., of Neelon, was also examined under the microscope. The rock may be referred to, at present, as a uralitic quartz-diabase. The original pyroxene is now represented by pale greenish, feebly pleochroic bastite and actinolite, much of the plagioclase is rather clear and fresh, but some has undergone considerable saussuritization. A little brownish hornblende is present. Sphene, in irregular grains, with black opaque cores of ilmenite, epidote and zoisite, are the principal other minerals noticed.

Mineralogical composition of altered norite from N½ lot 4, con. VI., Neelon.

The actinolite diorite and schist, with which the deposits at the Worthington, Mitchener, Totten and Macdonell or Gersdorffite mines are associated, are evidently highly altered forms of this norite. These deposits possess certain peculiarities in common with one another, which distinguish them from the other ore bodies, connected with the main mass of the norite. Some of the rock, collected at the Vermilion mine is possibly of the same type and age, but this was not definitely ascertained. As is evident from the foregoing, it is manifestly difficult, if not impossible, in all cases, to decide the question of the identity of every individual specimen of altered norite, or even the various separated masses, but in a broad way, these two norites are distinct and separate from one another, and the criteria already mentioned for distinguishing them will usually be found sufficient.

Other altered varieties of older norite.

Difficult in all cases to distinguish norites.

(3.) LAURENTIAN GRANITE AND DIORITE-GNEISSES.

The rocks usually classified as Laurentian, comprise a series of foliated, eruptive rocks, mainly of granitic and dioritic composition, crossing the southeastern corner of the Sudbury map, in the townships of Dill and Neelon, in the vicinity of the Wanapitei river. These rocks possess a well-marked foliation, this structure being determined not only by the alternation of lighter and darker coloured bands, but also by the parallel disposition and alignment of the component minerals. The lighter coloured bands are usually of the prevailing flesh-red tint, and are made up largely of quartz with orthoclase, microline and microperthite as the felspathic constituents, and these minerals, together with biotite in varying amount, make up the bulk of the rock. The darker coloured bands contain less quartz and very abundant mica, with oligoclase as the principal felspar. The biotite is often altered to

Laurentian rocks, where located.

General description.

Character of foliation.

Mineralogical composition.

chlorite. Muscovite and zircon are often present in small amount. Garnet is very abundant, of the prevailing almandine variety, and usually more or less rounded, but some of the well formed individuals show the faces of the rhombic dodecahedron and icositetrahedron. Perhaps the most interesting mineral is cyanite, which is abundant in certain portions of the rock, occurring both in the micaceous and felspathic bands. This mineral occurs in flat, blade-like crystals, with the prevailing bluish and whitish colours. In the micaceous bands, the colour is especially deep, and of a beautiful azure tint, somewhat unevenly distributed or cloud-like in its effect, the colour being often deepest in the centre of the crystals, gradually becoming colourless towards the margin. These crystals are arranged, for the most part, parallel to the foliation, but some individuals are disposed at considerable angles to this structure. Sillimanite or fibrolite is also occasionally present, especially on slickensided or jointing planes, and shows abundant evidence of pressure and stretching. These gneisses are distinctly of eruptive origin, and their intrusion through the quartzites and other clastic rocks is everywhere apparent, where the line of junction is so exposed, that the relationship between the two may be examined and studied.

Almandine garnet.

Cyanite abundant in certain portions.

Sillimanite on jointing planes.

Gneisses of eruptive origin.

4. UPPER HURONIAN (?) CLASTIC ROCKS.

The rocks, thus classified, occupy the large oval area situated immediately northwest of the main belt of the nickel bearing and kindred eruptives, and underlying the extensive clay plain, which has already been described as so eminently suitable for agricultural purposes. As a result of the first geological examination, these rocks were regarded by Dr. Bell as probably of Cambrian age, and have thus been coloured on all subsequent geological maps. Their precise geological age is still a matter of doubt, but the later work seems to indicate a close relationship both in origin and age, with the main masses of norite and micropegmatite. If, as seems probable, from the work already accomplished, these several separate ranges of nickel bearing norite are, in reality, the exposed portions of one continuous laccolite, with occasional minor irregularities or offsets, then, as illustrated by Dr. Coleman (¹), these youngest clastic rocks of the district will, no doubt, be shown to occupy a synclinal trough, overlying this deep platter-shaped sheet of intrusive rock.

Location of Upper Huronian rocks.

Rocks regarded by Dr. Bell as probably of Cambrian age.

Probable relative age.

Synclinal trough overlying norite.

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(1) Ann. Rep. Bur. of Mines, Ont. 1903, (illustration 52) pp. 288-289.

These rocks extend from the southeastern part of the township of Trill, to within a few miles of Wanapitei lake, the area being thus nearly thirty-five miles in length, with an extreme width of a little over eight miles.

Succession of clastic rocks.

They comprise, at the base, certain breccias and agglomerates, most of which, at least, are of pyroclastic origin, these rocks passing upward into black bituminous shales, while they are, in turn, overlaid by a comparatively coarse greywacke or felspathic sandstone.

Identification of breccia as volcanic glass breccia by Professor Williams.

The identification of the breccia at the base of this series, as a consolidated volcanic ash, was the result of microscopical studies undertaken by the late Prof. G. H. Williams, of material furnished him by Dr. Bell. The important fact of the occurrence, in these ancient rocks, of a volcanic glass breccia, the various minute details of structure being so exceptionally preserved through silicification, as to permit of its positive recognition, has always been a matter of general interest and comment, especially amongst those geologists, who regarded these earlier periods of the earth's history as characterized by exceptional and prolonged explosive volcanic activity.

Description communicated to Geological Society of America.

A description of this comparatively rare type of rock, was carefully prepared by Prof. Williams, and communicated to a meeting of the Geological Society of America, held on December 31st, 1890. These details were embodied in an appendix to Dr. Bell's paper on the nickel and copper deposits of this district, which was also read at this meeting (1).

Specimens from Onaping river.

The material submitted for examination, consisted of two small hand specimens, collected at the lowest falls on the Onaping river, in the township of Dowling. Prof. Williams' description (2) is so complete and satisfactory, that it may be quoted in this connection.

General description of volcanic breccia.

'In a hand specimen, this rock presents a nearly black felsitic matrix, in which are embedded sharply angular or slightly rounded fragments, varying from 1½ cm. in diameter, downwards to ultra-microscopic dimensions. These fragments are lighter in color than the matrix, but differ considerably among themselves in their tint, structure and composition. The majority resemble chalcedony in appearance, others are greenish, while some of the largest fragments are now replaced by a single calcite individual. Occasional small grains of clear vitreous quartz may also be detected, while specks of pyrrhotite are everywhere abundant. Many of the angular fragments show distinctly under the

Many angular vesiculear fragments.

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(1) Bull. Geol. Soc. Am. Vol. II. 1891, pp. 125-137.

(2) Ann. Rep. Geol. Surv. Can. Vol. V. 1890-91, Part F, pp. 74-76.

Flow structure.

Character of groundmass.

Arrangement of chlorite.

Quartz, calcite and felspar.

lens a flow or vesicular structure, which is still more apparent in a thin section of the rock when seen under the microscope. The fragments, even down to those of the smallest dimensions, have the angular form characteristic of glass sherds produced by explosive eruptions, with more or less coarsely vesicular structure. The flow structure is as perfectly marked by sinuous lines of globulites and microlites which terminate abruptly against the broken edge of the glass particle, as in the most recent vitrophyre. Minute spots of pyrrhotite are scattered throughout the section. The groundmass is of a dark colour, owing to the massing in it of minute black globulites, to whose nature the highest magnifying power gives no clue. Between crossed nicols it is seen to be made up largely of chalcedonic quartz, which has changed the easily destructible glass into a sort of jasper. Chlorite is also abundant, frequently arranged as a border of radiating scales around the edges of the fragments, so as to coat them green in the hand specimen. The larger grains are always a fine mosaic of interlocking quartz, but some of the smaller ones are composed of a unit individual of clear vitreous quartz. The only other minerals which could be identified in the section are calcite and a few grains of a glassy striated felspar. The presence of this latter mineral is very noteworthy, as we should expect it to have disappeared during the vicissitudes through which this rock has passed.'

Composite fragments also occur.

In other localities, this breccia shows a greater diversity in the character of the larger fragments, and composite rocks made up largely of quartz and felspar, either granite or recrystallized quartzite, frequently occur. Plagioclase and quartz, usually in angular or subangular pieces, are very often represented, while epidote and hornblende, also mentioned by Dr. Coleman, are likewise present in the thin sections examined by the writer.

Silica determination by Dr. Hoffmann

Chemical analysis by Dr. Walker.

No complete chemical analysis has yet been made of the individual specimens examined by Prof. Williams, but Dr. Hoffmann made a silica determination, showing it to contain 60.23 per cent. Dr. T. L. Walker however, has made an analysis of a specimen of this breccia, obtained from the north shore of Whitson lake, with the following results: (1).

$Si\,O_2$	59·93	Na_2O	3·80
$Al_2\,O_3$	12·12	$K_2\,O$	0·97
$Fe\ O$	10·56	Loss by ignition	1·57
$Mn\ O$	trace		
$Ca\ O$	4·49	Total........	98·63
$Mg\ O$	5·19		

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(1) Quart. Jour. Geol. Soc. Lon. Vol. LIII, 1897 p. 45.

Various sulphides, chiefly pyrite, but sometimes also pyrrhotite and chalcopyrite, are often abundantly disseminated through this rock, and not a few mining locations have been surveyed, intended to cover such deposits, which were regarded as possible mines. One of the most promising of these, visited by Mr. Leroy, was situated on the south half of lot 8, con. IV., of the township of Dowling, and the specimens secured were handed to Dr. Hoffmann for assay. The hand specimen shows a massive pyrrhotite, with which is associated a little chalcopyrite and a somewhat larger proportion of gangue. The pyrrhotite, when freed from the chalcopyrite and gangue, was found by Mr. F. G. Wait (1) to contain 0.26 per cent, of nickel with a trace of cobalt. Resting upon this breccia or agglomerate, are certain black bituminous shales, often with well developed slaty cleavages. This rock is made up principally of minute fragments of quartz, with intervening scales of chlorite and sericite, and abundantly disseminated, black, opaque particles of carbonaceous or bituminous matter. These slates sometimes contain fissures occupied by anthraxolite or vein anthracite, and a large outcropping of such material in the township of Balfour, occasioned considerable excitement some years ago. Samples of the surrounding rock, analyzed by Dr. Ellis, showed 6.8 per cent of carbon in the shale. (2) The highest rocks in this series are certain gray sandstones and shales, the former frequently containing concretions, which weather more rapidly than the matrix in which they are enclosed. Composite fragments can often be recognized with the naked eye, and the rock then assumes the character of a coarse grit. It is made up, principally of angular and subangular grains of quartz, embedded in a finer-grained base, composed of felspar, quartz, chlorite and mica. Zircon and tourmaline are also sometimes present. The dark colour of the rock is due to disseminations of innumerable, fine particles of opaque material, especially abundant in the felspar, and which are probably ilmenite.

Abundance of sulphides.

Deposits visited by Mr. Leroy.

Assay of pyrrhotite by F. G. Wait.

Presence of bituminous matter in shales.

Anthraxolite.

Amount of carbon in shale.

Composition of sandstones and shales.

(5.) Post Huronian.

(A.) GRANITE.

It has been customary, of late years, to speak of certain areas of acid intrusives, occurring in intimate association with the nickel bearing eruptive, as the 'younger granites.' Reference has already been made to their strange and anomalous behaviour with regard to the sulphide bearing norite, for wherever the line of junction, between these two classes of rock, has been examined, it

Younger granites.

Relation between granite and norite.

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(1) Ann. Rep. Geol. Surv. Can. Vol. XIII Part R, p. 35.

(2) Ann. Rep. Bur. of Mines, Ont. 1896 pp. 159-166.

presents a series of apparently conflicting phenomena, which, in the present state of our knowledge, cannot be satisfactorily interpreted or explained. The larger proportion of the evidence, so far available, seems decidedly in favour of regarding these granite rocks as of earlier generation than the norite or gabbro, and even in the vicinity of the Creighton mine, where the immediate junction is characterized by the presence of a narrow belt of intermediate composition between the granite or norite, Dr. Coleman states that 'on the whole, however, the impression is formed that the granitoid gneiss is older than the gabbro, the latter sometimes growing finer grained at the edge of the gneiss' (1). A reasonable explanation of the contradictory phenomena witnessed, seems to be closely connected with the manner and rate of cooling of the granite bathylith. This immense body of acid eruptive, as at present exposed at the surface by denudation, has not evidently resulted from the consolidation of a body of magma, the product of one simple act of plutonic activity, but is rather the result, locally at least, of several successive fusions and re-cementations, before the whole mass reached its final or present condition. The evidence of such successive periods of intrusion, is furnished by a study of the granite mass itself, for although over the larger part of the area, the granite is remarkably uniform in structure and composition, certain localities show rather sudden changes in these respects, with occasionally a sharp dividing line, thus indicating an apparent difference in age. All attempts, however, to trace out this apparent line of subdivision in detail, over any extent of country, proved futile, and the conclusion was reached, that the whole mass is very closely synchronous, and that no appreciable lapse of time in a geological sense, has occurred between the several dates, represented by these different phases of the granite. The rate of cooling, moreover, was extremely slow, much more so in fact than the norite, so that it is possible that, in certain instances, some portions may have been sufficiently consolidated to permit of the cooling against it of the norite, while in areas not far distant, some of the latest acid secretions of the granite penetrated and altered the norite or gabbro. There are two main types of these granites, the difference between the two being essentially one of structure, and although intermediate varieties between the two extremes are known to occur, such phases are relatively unimportant and may be ignored for purposes of general description. These two varieties are at present believed to be very approximately, at least, of the same age. One type of rock which occupies by far the largest area of any of these acid eruptives, is a very decided 'augen' or porphyritic granitite-gneiss. In places, this seems

Granitoid gneiss older than norite.

Explanation of contradictory phenomena.

Evidence of successive periods of intrusion.

Difference in rate of cooling.

Two main types of granite.

Approximately of same age.

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(1) Ann. Rep. Bur. of Mines, Ont., 1903, p. 245.

to pass into a finer-grained and more massive type, with ill-defined or no foliation, thus resembling the second variety, the type of which, however, forms two smaller and separated bathyliths occurring to the northeast of the main mass.

Transition between the two types of granite.

The coarser or 'augen' type presents such a strong resemblance, in every respect, to certain gneissoid rocks, occurring in the Laurentian, that it was indicated as part of this formation in the first geological map. It constitutes a well marked bathylith, intrusive through the older green schists and diorites, which it has greatly disturbed and altered, forming a belt to the south of the main mass of the sulphide bearing norite, and extending from the second lot in the township of Denison, to a point a little east of the boundary between Snider and McKim townships, near the Copper Cliff mine. The mass is thus about thirteen miles in length, with an average width varying from one to two miles. It forms a very striking and beautiful rock, eminently suitable for building or ornamental purposes. It has been used in the building of the main office at Copper Cliff, as also for mantles in the manager's house at Victoria Mines.

Resemblance of 'augen' type to Laurantian.

Outline of larged bathylith.

Suitable for building and ornamental purposes.

Under the microscope, the thin section shows the rock to be made up chiefly of microcline, orthoclase, albite, oligoclase, biotite and quartz, with epidote, sphene and apatite as accessory minerals, and calcite, epidote, zoisite, sericite and chlorite as secondary products of decomposition. The orthoclase and microcline sometimes occur free, but, for the most part, are intergrown with the albite, forming both microcline-and orthoclase-microperthite. The quartz is the usual granitic variety, frequently showing intense strain shadows and sometimes granulated into a fine interlocking mosaic. The felspars of the rock, although like the quartz, often much cracked, broken and granulated, are comparatively fresh. Reddish-brown iron oxide has spread through the cracks, giving a cloudy or stained appearance to many of the grains. Much of the oligoclase has undergone considerable saussuritization, the resulting products being epidote, zoisite and sericite. It is usually stained a deep reddish-brown colour. The biotite is usually 'bleached' and has often undergone more or less complete chloritization. Sphene and epidote are often embedded in the biotite. Apatite is frequently present in the usual acicular prisms, while occasionally, a little calcite was noticed in thin sections.

Microscopical determination of minerals.

The 'augen' are usually made up of a comparatively coarse-grained aggregate of microperthite or microcline, together with a much smaller proportion of quartz. More rarely, it is a single crystal of felspar, often a Carlsbad twin, rarely, however, with sharp or well defined boundaries.

Composition of 'augen'

In the vicinity of the Creighton mine, the granite of the main bathylith comes in immediate juxtaposition with the nickel bearing norite, while to the southwest in the vicinity of the Gertrude mine, as well as to the northeast from the North Star mine and beyond, considerable areas of the peculiar granite and greenstone breccia intervene between the two rocks. As has been stated, there is the clearest evidence at the Creighton mine, of considerable reaction between the granite and norite, the former being often impregnated for a considerable distance from the contact with the nickel and copper bearing sulphides, while, in addition, certain portions of granite are unusually basic, presenting a rock of intermediate composition between the granite and norite, with deep flesh-red porphyritic individuals, often Carlsbad twins of orthoclase, microcline or microperthite, embedded in a groundmass made up principally of biotite, hornblende, epidote and sphene, the latter containing black opaque cores, presumably of ilmenite.

Reaction between granite and norites.

Two smaller areas of finer-grained granite.

The finer grained variety of granite is characteristic of two areas. The smaller one is situated immediately east of the Lady Violet mine, and extends a little north of the Manitoulin and North Shore railway, on the boundary between McKim and Snider townships. It covers a considerable portion of lot 1., Con. IV., of the township of Snider.

Location of larger area of fine-grained granite.

The other and larger area, extends from the main line of the Canadian Pacific railway, a little southeast of the Murray mine, northeast to within a quarter of a mile of the Little Stobie mine. It thus constitutes an oval area, measuring about three miles in length, and averaging about three quarters of a mile in width. A microscopical examination of the thin section. shows an aggregate of quartz, orthoclase, plagioclase, biotite, hornblende, magnetite and zircon. The rock has evidently been subjected to great crushing. The structure is by no means uniform, but larger fragments are embedded in a finer grained mosaic, which has resulted, in great part, from their peripheral granulation. The magnetite is highly titaniferous, as it is often surrounded by borders of leucoxene or the more normal sphene. Besides these, a very small and irregularly shaped area crosses the Manitoulin and North Shore railway, immediately east of Pump lake, on lot 1, con IV., of Snider township. It has a general resemblance to the coarse 'augen' variety. This small mass measures about 850 feet long and from 150 to 500 feet wide.

Microscopical determination.

Small area of coarse granite near Pump lake.

Small intrusions of granite northwest of Murray mine.

About two miles west of the Murray mine, Walker mentions that the nickel bearing eruptive is cut by two separate intrusions of fine-grained, pinkish, biotite-granite, which send off apophyses into the surrounding greenstone. The wider of the intrusions is about 100 yards broad, while the smaller is less than 60 yards. The microscope shows that quartz, orthoclase, plagioclase and biotite, are the chief constituents. Considerable areas, in the vicinity of the line of junction between these granites and the older greenstones, are characterized by the presence of a breccia, made up of an extremely intricate intrusion or penetration of the greenish schistose rocks by dykes and irregular masses of granitic material. The chief alteration noticed in connection with the greenstone, is the development of biotite at the expense of the original hornblende, and the replacement of the plagioclase by a fine mosaic of secondary plagioclase, quartz and epidote, the rock being thus a well formed mica or biotite schist. Subsequent differential movements have occasioned very considerable deformation, and some portions of the resultant rock mass represent very perfect and characteristic pseudo-conglomerates. Areas of these breccias are often big enough to be shown on maps of ordinarily large scale. They are espetially noticeable east and southeast of the Gertrude mine, and between this and the Creighton mine, and some of the cuttings of the Manitoulin and North Shore railway, between these two mines, have been made through hills of this breccia. It seems to occupy a lenticular area, intervening between the norite and the granite, the widest part being a little over three quarters of a mile, while the length from northeast to southwest is about three miles. To the northeast, in the vicinity of the North Star mine and beyond, as far as Clarabelle lake, considerable areas are underlaid by this breccia, while in the neighbourhood of the Murray mine, they are especially noticeable and well developed. The manager's house at Copper Cliff, is located on a rocky knoll, made up of this breccia, and a comparatively narrow band of this rock extends for a short distance in a southwesterly direction.

Breccia of green schist and granite.

Location of main masses of breccia.

Breccia at Murray and Copper Cliff mines.

In addition, the main mass of the granite bathylith contains frequent inclusions, often of large size, of these older greenstones and schists, the reason for their presence and occasional abundance being readily explained by Dr. Daly as due to 'stoping,' as he terms the phenomenon of the detaching of portions of the original material overlying or enclosing a bathylith, and the inclusion of such fragments in the mass of the original magma. (1)

Inclusion of greenstone in granite.

Reason for presence of greenstone fragments.

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(1) Amer. Jour. Sc. Vol. XVI, 1903, p. 108.

(5.) Post Huronian.

(B.) NICKEL BEARING ERUPTIVE.

Early recognation of intimate connection between basic eruptives and sulphide deposits.

Soon after the discovery of these nickel and copper deposits, it was remarked that all of the rich and extensive ore bodies occurred in intimate connection with certain basic eruptive rocks, of medium texture, and which for convenience of description, and in the absence of more precise information, were usually referred to under the names of greenstone and diorite. The first published microscopical descriptions were all in substantial agreement, in regarding the prevailing type of the nickel bearing eruptive as made up essentially of plagioclase and hornblende, with a smaller proportion of biotite and quartz, while ilmenite and apatite, with variable quantities of pyrrhotite and chalcopyrite, were the usual accessory constitutents. The rock was therefore regarded as an intrusive gabbro or diabase, which, owing to subsequent metamorphism, had its pyroxenic components changed to secondary hornblende or uralite. Rocks quite like these had been studied in many regions, where they could be traced with certainty into basic eruptives of normal character, and it was confidently predicted by the late Prof. G. H. Williams, who was the first to make any detailed petrographical examination of these rocks, that 'specimens might be collected at some of these localities which would establish positively both the original form, and the course of alteration of the present specimens.' (1)

First microscopical descriptions.

Prediction of recognition of true nature of eruptive.

Included in the same suite of specimens as the foregoing, all of which had been sent by Dr. Bell to Prof. Williams for identification and description, was one, which had been collected near the Dominion mine, in the township of Blezard, but which, in the hurry of a first examination, was regarded as occurring in the form of a dyke. This rock, the exceptional character of which was noted at the time by Prof. Williams, and which was described as a 'quartz-hypersthene-gabbro with accessory biotite' (2), was in reality a practically unaltered representative of the nickel bearing eruptive, although its identity as such, was not suspected until some years afterwards.

Dominion mine eruptive first described as dyke.

All of these first microscopical determinations, therefore, showed a normal type of greenstone, differing in no essential particular from others similarly altered, and with no apparent reason for the development of such unusually large and rich deposits of sulphide material. At the same time, the field and prospectors term of diorite was justified, as also the names proposed after more detailed microscopical examination, such as uralitic or gabbro-diorite, uralitic diabase, etc.

Prospector's name of diorite justified.

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(1) Ann. Rep. Geol. Surv. Can. Vol. V. 1890-91, Part F., pp. 60 & 62.

(2) Ann. Rep. Geol. Surv. Can. Vol. V. 1890-91, Part F. pp. 77-78.

It is to be regretted, therefore, that although great care was exercised in the collection of these first or type specimens, attention was directed. chiefly, to the selection of material in immediate association with the ore bodies, and the rocks thus obtained, were in such advanced stages of decomposition, that no very definite or precise information was possible in regard to their original composition or true affinities. As a conseqence of this, the opinion prevails that the whole of the eruptive in the vicinity of these nickel deposits, is completely altered, whereas the very opposite appears to be the case, and most of the writer's collection of fresh and unaltered material was obtained in the immediate vicinity of the various mines. In this connection it may be remarked that some of these hand specimens, containing as much as from 5 to 10 per cent of the sulphides, have undergone so little metamorphism, as to permit of the positive identification of all the prevailing minerals, including hypersthene, enstatite, diallage, olivine and labradorite.

In spite of great care exercised first specimens all greatly altered.

Many fresh specimens later secured from vicinity of mines often containing much sulphide material.

In 1892, the late Baron von Foullon published the first determination of the nickel bearing eruptive, occurring in the vicinity of the Murray mine, showing it to be a gabbro, closely related to the norites, his descriptions being prepared after a study of material collected at this locality, in the summer of 1890. In 1893, Dr. A. P. Coleman identified the eruptive of the Northern Nickel Range as a gabbro containing both diallage and hypersthene.

Descriptions of norite by von Foullon and Coleman.

The true significance of these discoveries and isolated descriptions, was not, however, fully appreciated, until the appearance of Dr. Walker's results, the issuing of this publication marking a very signal advance in our knowledge, regarding the origin and relationship of these sulphide deposits and their associated rocks.

Fuller descriptions by Dr. Walker

The nickel bearing eruptive, characteristic of the three main belts or ranges, may, for purposes of description, be considered under two divisions.

Two divisions of nickel bearing eruptive.

I. A basic portion :—Including certain gabbroid rocks, chiefly, at least, of the norite facies, with their derivative diorites, with which the nickel and copper bearing sulphides are immediately associated.

II. An acidic portion :—Comprising large areas of rock of granitic type, with well marked gneissoid structure, the prevalence and abundance of the graphic intergrowth of the quartz and felspar, known as granophyre or micropegmatite, having suggested the name 'micropegmatite,' by which this rock is now generally known.

The least altered phase of the basic portion of the eruptive is represented by what may be referred to as 'norite'. The rock is some-

Name for nickel bearing eruptive.

times called a 'quartz-hypersthene-gabbro', but for general purposes the former name is preferred.

Eruptive ef exceptional interest,

Presence of original quartz and hypersthene.

Granophyre.

Biotite and quartz conspicuous.

The microscopical examination shows the rock to be an eruptive of rather exceptional character and interest. It belongs to the general family of gabbros, but with distinct traces, and, at times, well marked diabasic or ophitic structure. The prevalence and usual preponderance of hypersthene or enstatite, show its close affinity with the norites, while it contains, what is very exceptional for such a rock type, an abundance of original quartz. In fact, many specimens could be secured, which contain nearly as much quartz as an ordinary hornblende granite. In some instances, noticeably at the Copper Cliff mines, a large quantity of micropegmatite or granophyre is present, the felspathic constituent of this graphic intergrowth being usually plagioclase. Exposures show a massive, medium to coarse-grained, dark-grayish, greenish-gray or brownish rock, which is often almost black in color on freshly broken surfaces. Scales of deep brown biotite are usually conspicuous, while the quartz is perhaps equally so, in very characteristic sapphire-blue or purplish grains, the color which is often seen in the phenocrysts of quartz-porphyries.

Norite decomposes readily.

These rocks do not offer any very effectual resistance to processes of decomposition and erosion, and, as a consequence, the area characterized by their presence is, generally, one of low relief.

Spheroidal weathering.

Spheroidal weathering is characteristic, but not so pronounced as in the case of the later dykes of the olivine-diabase.

Development of hypersthene. and enstatite.

Alteration of rhombic pyroxene.

The orthorhombic pyroxene, either hypersthene or enstatite, shows a distinct approach to perfection of crystallographic outline, and, in many cases was the first of the essential minerals to form. In occasional instances, the hypersthene is unaccompanied by a monoclinic pyroxene, as in some of the specimens collected in the vicinity of the Blezard mine. It is often, by far, the most abundant of the coloured constituents, as at the Murray mine, where the diallage is only occasionally represented, while almost the whole rock mass is made up of hypersthene, in various stages of decomposition, the small and infrequent interspaces being occupied by plagioclase. The hypersthene is, as a rule, rather faintly pleochroic, although specimens from the vicinity of the Blezard mine, and from a railway cutting about one mile and a half north-west of the Murray mine, are very strongly pleochroic, rose red to pale yellow fiish-green. The enstatite is also colourless in thin section, and,in contradistinction to the hypersthene, exhibits little or no pleochroism. Both the hypersthene and the enstatite are very liable to decomposition, so that, in most cases, areas of this mineral, are replaced by an aggregate of light-green, non-pleochroic, brilliantly polarizing, fibrous or scaly serpentine (bastite). This alteration is often accompanied by the separation of minute grains of magnetite. In most cases, even the fresh individuals of hypersthene are bordered by a compact, strongly pleochroic, green hornblende which is doubtless an original constituent. This primary hornblende, likewise, forms borders on areas showing the complete bastitic alteration. In addition to this, there is undoubted secondary hornblende resulting from the alteration, first, of the bastite into actinolite, and this in turn, to the ordinary type of green hornblende.

Presence of both primary and secondary hornblende.

The monoclinic pyroxene, which is usually present in subordinate amount, is likewise frequently bordered by primary hornblende, and thus, the individuals of these two pyroxenes cannot be distinguished from one another, in specimens which have undergone any advanced decomposition. Sometimes, both pyroxenes show the presence of the characteristic, minute, tabular interpositions or schillerization products but, as a rule, these are absent.

Diallage.

The diallage is distinguished from the orthorhombic pyroxene chiefly by the absence of pleochroism, its inclined extinction, and frequent polysynthetic twinning, while it usually shows a lower index of refraction with higher double refraction. Olivine is present in small amount in the norite obtained from the Little Stobie mine, but most of it is altered to an aggregate of deep coloured scaly serpentine, talc and magnetite. Biotite is an almost invariable consituent and is usually rather abundant, in large plates and is undoubtedly of primary origin. The plagioclase is usually in broadly twinned, stout, lath-shaped or tabular crystals, whose frequent interlacing arrangement produces the characteristic, rude, ophitic structure. Separations by means of Thoulet's heavy solution, as well as the extinction angles, show that this plagioclase is labradorite. The presence of innumerable, brown, dust like inclusions, presumably of ilmenite, gives to the felspar its prevailing dark colour.

Means of distinguishing the two pyroxenes

Olivine rareiy present.

Separations by heavy solution.

Quartz and occasionally granophyre fills most of the irregular interspaces between the other constituents, although, in the norite from the Creighton mine, microcline almost invariably accompanies this interstitial quartz. Apatite, magnetite, which is usually highly titaniferous, zircon and grains of pyrite, pyrrhotite and chalcopyrite are almost always present. These sulphides are distinctly of primary origin, and were among the earliest of the minerals to crystallize from the original magma, antedating even the magnetite, in some cases, for grains of pyrrhotite were noticed completely enclosed by the iron ore. The sulphides occur, for the most part, intimately associated with, and

Quartz and granophyre.

Microcline at Creighton mine.

Primary origin of sulphides.

Sulphides intimately associated with one another.

frequently embedded in the coloured constituents, in much the same way as the magnetite, from which they can only be distinguished by the difference in colour in reflected light. The pyrrhotite and chalcopyrite are often very intimately associated, so that they are extremely difficult of separation, even the smallest grains showing intimate intergrowths of these minerals with one another. These sulphides frequently occur in those portions of the norite which have suffered so little from dynamic metamorphism, that only an occasional dislocation of a plagioclase crystal is noticed, while the same exposures have been so little affected by hydrochemical agencies, that such readily alterable minerals as hypersthene, enstatite, olivine and diallage are still plainly recognizable in such specimens. The sulphide material, in such cases, is often not subordinate in amount, but is so abundantly disseminated as to characterize the rock, and justify the name of 'pyrrhotite-norite' which is sometimes applied to it.

Sulphides occur in unaltered forms of norite.

Altered varieties of norite more abundant.

Although a considerable number of specimens were secured, representative of the comparatively unaltered norite, by far the larger proportion of the material collected consisted of a massive, usually coarse gabbro-diorite in various stages of alteration. Very few of these show even traces of dynamic metamorphism, and, as a rule, the ophitic structure, produced mainly by the interlacing arrangement of the plagioclase crystals, is quite undisturbed. The alteration is mainly due to hydrochemical agencies, and affects the pyroxenic minerals, decomposing these to a pale, yellowish-green serpentine, sometimes of the ordinary type, but usually of the bastite variety. Actinolite also results from the alteration of the pyroxenes. The compact borders of primary hornblende often surrounding the original pyroxenes, are evidently made up of much more stable material, not having been affected by any of these changes. The areas formerly occupied by the pyroxene are, therefore, replaced by bastite or actinolite, the hornblende borders remaining unaffected, the individuals thus decomposed being referred to as uralite. No distinction can be drawn between grains which represent hypersthene or diallage, as both of these minerals apparently decompose to closely related, if not identical material. The labradorite is usually quite fresh, in tabular or broad blade-like forms, with a brownish colour of varying shades, which is so prevalent in the norites. Occasionally it shows incipient decomposition to the usual saussuritic products, mainly sericite, but also epidote and zoisite. Biotite is always present and conspicuous in large plates with strong pleochroism. It is sometimes intergrown with the hornblende and has also undergone considerable 'bleaching'. It usually contains comparatively large, irregular grains of magnetite. Quartz is always present, and sometimes

Pyroxenes mainly decomposed.

Probable identity of decomposition product of both pyroxenes.

Plagioclase usually quite fresh.

Character of other mineral constituents.

abundant, filling up the irregular interspaces between the other constituents, Highly titaniferous magnetite and apatite are also always present, but in small amount, while the pyrrhotite and chalcopyrite vary in amount, from occasionally disseminated grains, to such quantities as ensure the use of the mass as an ore of nickel and copper.

Acid portion of nickel bearing eruptive

In addition to the norite and diorite, a more acid rock of granitic composition and prevailing gneissoid structure occurs, which cannot be separated genetically from the more basic portion with which the sulphides are more directly associated. This rock has usually been referred to as 'micropegmatite' a name first suggested by the late Prof. G. H. Williams. ( ) There is no sharp line of demarcation between the acidic and basic portions of the nickel bearing eruptive, but the change, though gradual, is usually sharp enough to enable a boundary to be placed between these two types, with tolerable accuracy. Outcrops of this rock are evenly banded or foliated, with a distinct strike and dip, usually porphyritic, weather a pale reddish or grayish colour and are frequently intersected by irregular and often intricate vein-like, masses of quartz, evidently of pegmatitic origin. On freshly exposed surfaces, the rock is usually dark coloured, with abundantly disseminated, small, reddish or yellowish phenocrysts of felspar. Orthoclase is often present in considerable amount, and, towards the outer edge of the mass, is the predominant felspathic constituent, but plagioclase (oligoclase or oligoclase-andesine) is usually more or less abundant. Microperthite and microcline are also often present, but in subordinate amount. Much of the felspar is somewhat turbid owing to decomposition. Biotite is the prevailing ferromagnesian mineral and much of it is 'bleached' and altered to chlorite. It is usually in small irregular, tattered scales and plates, arranged in narrow, approximately parallel bands, gently curving around and among the larger phenocrysts of felspar. The abundance of the biotite, and its frequent alteration to chlorite, give the prevailing dark colour to the rock on fresh surfaces. The transition type between the micropegmatite and the norite, shows a varying proportion of hornblende, which mineral, as a general rule, diminishes in amount in passing outward from the norite, although certain bands of relatively greater basicity show an appreciable amount of this mineral, even at a considerable distance from the line of junction. One of the most noteworthy points, in connection with this gneissoid rock, is the prevalence and abundant development of micropegmatite or granophyre, and also the fact that plagioclase and quartz are most frequently the component minerals

Micropegmatite.

Absence of sharp line of division.

General characters of micropegmatite.

Microscopical determination of mineral constituents.

Transition type between micropegmatite and norite.

Prevalence and characteristics of granophyre.

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(1) Ann. Rep. Geol. Surv. Can. Vol. V, 1890-91, Part. F. p. 78.

forming this graphic intergrowth. The micropegmatite, together with the bisilicate material, chiefly biotite or chlorite, and sometimes hornblende and accessory epidote, ilmenite and sphene, form a groundmass, in which the comparatively large phenocrysts of felspar, chiefly plagioclase, but sometimes also orthoclase and microperthite, are embedded. The granophyre or micropegmatite very often stretches out, in various directions from a central portion or body, made up of well twinned and rather sharply bounded crystals of plagioclase. The effect of pressure is very noticeable in all the thin sections, not only in the strain-shadows, but also in the dislocation of the felspar individuals, and the abundant development of the fine interstitial quartz and felspar.

Granophyre composed of plagioclase and quartz.

Micropegmatite formerly coloured as Laurentian.

On the first geological map, this micropegmatite was included with, and coloured as, a part of the Laurentian, the reddish colour, gneissic structure, and general behaviour, being the main factors which determined this classification.

Chemical composition of transitional types between micropegmatite and norite by Walker.

The variation in the chemical composition, marking the transition from the norite to the micropegmatite, is well illustrated by a series of analyses made by Dr. T. L. Walker (1) from specimens obtained along the Blezard mine crossing. The specimens range from south to north, from I to V. Analysis No. IV is by Mr. C. B. Fox, M. A.

	I	II	III	IV	V
SiO_2	49·90	51·52	64·85	69·27	67·76
TiO_2	1·47	1·39	.....	0·78	0·46
$P_2 0_5$	0 17	0·10	0·24	0·06	0·19
$Al_2 0_3$ ...	16·32	19·77	11·44	12·56	14·00
$Fe_2 0_3$ ...	....	0·47	2·94	2·89	.. ..
Fe 0	13·54	6·77	6·02	4·51	5·18
Ca 0	6·58	8·16	3·49	1·44	4·28
Mg 0	6·22	6·49	1·60	0·91	1·00
Mn 0	trace	trace	trace	trace	trace
K_2 0	2·25	0·70	3 02	3·05	1·19
Na_2 0 ...	1·82	2·66	3·92	3 12	5·22
H_2 0	0·76	1·68	0·78	0·76	1·01
Totals....	99·03	99·71	98·30	99·35	100·29
Specific gravity....	3·026	2·832	2·788	2·724	2·709

Norite is one continuous band and not separate belts as formerly supposed.

According to the present state of our knowledge, there are three main belts of norite, with which workable deposits of the various sulphides carrying nickel and copper occur. Until recently, these were believed to be entirely distinct and separated, but the later, more detailed geological examinations are tending to prove that these are all portions of a geological unit, and all referable to one continuous mass. They have always been regarded as essentially the same in origin and mineralogical composition and approximately, at least, of the same geological age. Two of these belts are not included on the accompanying map sheets and so far, none of the deposits occurring in association with them, have ever been operated as mines, producing ore for shipping and smelting purposes.

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(1) Quart. Jour. Geol. Soc. Lon. Vol. LIII, February, 1897, p. 56.

Outlines of Northern Nickel Range.

The most northerly of these bands known as the 'Northern Nickel Range' starts from the old Ross mine (W. R. 5), near the line, between lots 5 and 6, on the line between con's. III and IV., of the township of Foy, and extends in an east-southeast direction through the township of Bowell, where on lot 6, con. II., it branches. One offset runs southeast, into the townships of Lumsden and Morgan, where its limits have not been definitely ascertained. The main band, however, runs to the east, cutting across the township of Wissner, and crosses the Vermilion river, immediately north of Bronson lake. Trending still more to the north, it connects with the large area of basic rocks, occurring to the west of Wanapitei lake. This mass extends, for the most part, in a southerly direction, and, as far as at present ascertained, is buried beneath the sand and gravel plains of the eastern part of Garson and the western portion of Falconbridge. It is, as yet, a matter of conjecture, whether this mass is continuous with the southern or main belt of the norite, which to the east of lot 3, in con. III., of Garson, is likewise covered up by the heavy mantle of drift. It is probable, however, that this main belt is continuous beneath the drift, as far, at least, as the outcrops of norite occurring on cons. IV and V., of Falconbridge. It may be possible, with the assistance of delicate magnetic instruments, to trace out this connection, but this work will be difficult and tedious, on account of the great accumulation of drift material, which is sometimes over 100 feet in depth.

Probability of continuity of norite beneath the drift east of Garson.

Difficulties of tracing belt.

Levack Nickel Range.

A second important band of norite occupies an approximately intermediate position between the other two, and so may be referred to as the 'Middle Nickel Range,' although it is likewise known as the 'Levack Nickel Range,' while Walker refers to it under the name of the 'Windy lake eruptive.' According to present information, this band starts about lot 12, con. III., of the township of Trill, extends north and northeast through this township into Cascaden, and crossing under Windy lake, goes on uninterruptedly through the northwest corner of Dowling, to lot 2, con. IV., of Levack township. Little information is available in regard to the geology of the intervening

Outlines.

Absence of information of area between Ross mine and Levack township.

stretch of country, between this point and the Ross mine, and it is possible that this gap may be filled in, by extending this norite range still further to the northeast. The area to the east and southeast is known to be occupied by the acid differentiate of the norite, (micropegmatite) so that a connection between the Levack and the Northern Nickel Range, is well within the limits of possibility. To the southwest, the Levack Range reached within two miles of the old Sultana and Trillabelle nickel mines, so that, in this direction also, a connection may be made with the southern or main belt of the norite. The celebrated Levack nickel deposits are developed along the northern contact of this band with the granitite-gneiss included as Laurentian.

Probable connection with Main Nickel Range.

By far the largest and most important band of norite, however is what is known as the 'Southern or Main Nickel Range', a portion of which has been described by Dr. Walker under the name of the 'Whitson lake eruptive'. Its southeastern limit, in all probability, consists of a comparatively narrow band of basic eruptive material, crossing the southern portion of Trill, and extending thence into the northeastern part of Drury township. Its possible connection in this direction with the Middle or Levack Nickel Range, has already been discussed. From Drury, the band of norite extends eastward, crossing the southern half of lot 12, con. V., of Denison. From this point, it has been traced continuously, in a northeast direction, for a distance of about thirty-five miles, as far as lot 3, con. III., of Garson, where the exposures pass under the extensive accumulation of drift material. At the Victoria mines, the basic portion of the intrusive is rather less than a mile in width, but at the crossing of the Vermilion river, this width is increased to one mile and three quarters, while in the vicinity of the Creighton mine, the norite is a little over two miles wide. Through the townships of Snider, McKim and Blezard, the width of the norite is fairly uniform, averaging about one mile and a half gradually becoming narrower until Garson township is reached, where the basic portion of the nickel bearing eruptive, is scarcely half a mile in width.

Outlines of Main Nickel Range.

Width of main mass of norite.

On lot 2, con. IV., of the township of Snider, this main belt of norite sends off a narrow, dyke-like extension or offset, in a southeasterly direction, on which are situated most of the mines of the Canadian Copper Company, at Copper Cliff. This band runs across the northeast end of Clarabelle lake, and crossing Lady Macdonald lake, it runs with unbroken continuity as far as No. 2 mine, where its further extension southward is covered up with drift. Mine No. 2, with its extensions to the north, mines Nos. 4, 5 and 6, are all immediately associated with this narrow, dyke-like form, while the

Copper Cliff mines offset.

Location of mines on this offset.

Lady Violet mine is located at the eastern junction of the norite with the granite, a short distance northeast of the point where it joins the main mass.

Unnecessary to give details of distribution of micropegmatite

It is unnecessary to furnish similar details of the distribution of the micropegmatite or acid portion of the nickel bearing eruptive, but the area underlaid by this rock, is considerably in excess of the basic portion, as shown on the map.

Character and location of Copper Cliff mine.

The famous old Copper Cliff mine is a veritable chimney of ore, occurring in connection with an isolated stock of norite, which comes in contact with felspathic quartzites and green schist. The openings in the vicinity of the Ontario Smelting Works belong to three separate masses of norite, which are surrounded by banded tuffs and quartzite. It is difficult to obtain specimens from the small area of norite on which the Evans mine is situated, sufficiently free from the sulphide material, for purposes of examination.

General association of the various mines.

The Little Stobie mine, Dominion, Davis property, Kirkwood and Cryderman mines, are situated on the borders of the main belt of norite with green schist. The Stobie and Frood mines occur in conjunction with comparatively small stocks or areas of norite, which are separated from one another. The Elsie mine occurs at the junction between norite, on the one hand, and green schist and hornblende porphyrite, on the other. The Murray mine occurs at the junction between the granite and greenstone breccias and green schists on the one hand, and the main band of norite on the other; while the old Cameron mine, farther to the northeast, is found at the junction between the granite and the norite. The North Star and Creighton mines occur at the junction between the granite and the norite.

All deposits at or near the line of contact of the norite and older rocks.

The various openings known as the Gertrude mine, are located along the junction between the main band of norite, and a breccia made up of the granite intrusive through the older greenstone and schists. The main shaft of the Victoria mines is at the end of a small offset, connected with the main mass at the junction between the norite and the older green schists. Without exception, all of these immense bodies of sulphide material, are situated at the immediate contact between the intrusive norite and the older rocks, in such a way as to indicate in the clearest manner, their common origin.

(C.) LATER DYKES OF OLIVINE DIABASE.

Physical characters of olivine diabase.

The rock usually designated olivine diabase, and characteristic of what has been called the later dykes, is very uniform in mineralogical composition and structure. Hand specimens show a rock which is dark-gray, greenish-gray, to almost black, with spheroidal rusty weathering, which is very characteristic. In many instances, exposures exhibit a rude basaltic structure and are frequently porphyritic, with phenocrysts of yellowish or greenish labradorite, often an inch, or even more in diameter. The alteration of these phenocrysts produces the mineral 'huronite', so named by Thomson. These dykes possess well marked selvages of fine-grained, occasionally glassy material (tachylite), and present every gradation between basalt and diabase. The thin section of the fairly coarse rock shows a remarkably fresh olivine-diabase, made up chiefly of plagioclase, augite and olivine. The plagioclase is the principal constituent and is generally quite fresh and glassy, although occasionally somewhat turbid, as a result of incipient decomposition. Being the earliest constituent to crystallize, it is in idiomorphic, well twinned, tabular or lath-shaped crystals, which have a marked ophitic arrangement. The extinction angles clearly indicate labradorite. The twinning is according to the albite law, but a combination of the albite and pericline law, is very common. Occasional individuals exhibit twinning according to the rarer baveno law. The augite shows a very irregular or jagged outline, with characteristic imperfect or interrupted cleavages. It is reddish-brown to violet in colour, and very distinctly pleochroic. The olivine occurs in more or less rounded, pale yellow grains, and sometimes fills in the spaces between the felspar crystals. It is remarkably fresh, but occasionally shows decomposition to a deep green, compact serpentine (antigorite).

Phenocrysts of 'huronite'

Microscopical structure and composition.

Order of generation of mineral constituents.

Apatite is very abundant, in the usual acicular prismatic forms, and the opaque constituent is probably ilmenite. Some of the thin sections are very instructive, especially as regards the order of crystallization of the various mineral constituents. Apatite was certainly the first to crystallize, as it occurs in sharp, well defined, elongated prisms which are embedded in, or pierce the other constituents. The labradorite has, in most cases, at least, crystallized before the augite, but its relation to the olivine is not quite so distinct. In some cases, the olivine has the rounded outline it usually assumes when its crystallization is not interfered with, but often it may be found occupying the triangular interspaces between the felspar laths, or sharply moulded upon them. It appears therefore, that the period of the crystallization of the olivine, certainly overlapped that of the labradorite, although in general, the olivine is distinctly earlier. Most of the ilmenite, likewise, is earlier than the plagioclase, but occasional individuals contain crystals of olivine and plagioclase, showing that some of the ilmenite formed after the olivine and plagioclase.

A quantitative analysis of a specimen from the big dyke near Murray mine, gave Dr. Walker (¹) the following results :

Chemical analysis of olivine-diabase of Murray mine by Dr. Walker.

SiO_2	47·22
Al_2O_3	16·52
Fe_2O_3	3·32
FeO	12·40
MnO	0·04
CaO	9·61
MgO	3·33
K_2O	0·67
Na_2O	3·40
TiO_2	3 62
P_2O_5	0·33
BaO	0·01
CuO	trace
NiO	0·0275
CoO	0·0055
Loss by ignition	0·30
Total	100·803
Specific gravity	3·01

These dykes of olivine-diabase are distinctly later in age than the rest of the associated rocks. They cut the greenstones and associated micropegmatite, as well as the ore bodies themselves. They likewise cut the tuffs, breccias and quartzites, although one dyke was noticed, which did not reach the summit of the quartzites, but was cooled against the upper beds.

Relative age of dykes.

As a rule, most of these dykes are remarkably fresh and unaltered and all of those mapped as occurring in the vicinity of the Murray mine, are of this description. On the other hand, with the single exception of the large dyke which runs in a northwest direction near the Ontario Smelting Works, all of the others are much altered and decomposed, and thin sections prepared from these, cannot be distinguished from the finer grained and more basic, altered facies of the norite. The

As a rule, rock remarkably fresh and unaltered.

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(1) Quart. Jour. Geol. Soc. Lon., February, 1897, p. 63.

Altered varieties of diabase at Cpper Cliff.

boundaries between the bisilicates and plagioclase are not well defined, the latter containing scattered shreds and grains of hornblende and biotite. The plagioclase shows the same cloud-like arrangement of sub-microscopic inclusions, presumably of ilmenite. The hornblende is in small, strongly pleochroic individuals, and is very abundant. Biotite is also abundant, while the ilmenite is largely represented by sphene. The ophitic structure still remains, but is not so pronounced. Most of the plagioclase is quite fresh, but some of it is altered to a saussuritic aggregate. Quartz is fairly abundant, filling in small, irregular interspaces between the other constituents. Small grains of sulphide material are also disseminated through the rock. The occurrence of such a rock in dyke-like form, with the same mineralogical composition of the norite, indicates that these dykes at least, are later and differentiated portions of the norite, representing the dying efforts of the very pronounced and long continued vulcanism. The occasional presence of olivine in the norite of the Little Stobie mine, and the recognition of quartz in some of these later dykes, have supplied the links hitherto missing and necessary for a proper understanding of the relationship existing between these two rocks. As shown by Walker, in the analysis quoted of a fresh type, this olivine-diabase contains small quantities of copper, nickel, and cobalt, which the same author regards as original constituents of the olivine-diabase magma. The relations of these dykes to the various ore bodies through which they are intruded, show distinctly, that these latter had already attained their present dimensions, at some time previous to the intrusion of the dykes. For the most part, they have a fairly constant direction, but present frequent broad curves and occasional faults. Two of the largest dykes met with, vary in width from 150 to 200 feet, and were traced with practically unbroken continuity, from the northwest corner of McKim township, southeast to Ramsay lake. There is no local enrichment whatever of the ore bodies, in the vicinity of the dykes, as has frequently been surmised. The influence occasioned by their passage through these ore bodies is extremely local and very insignificant. In the vicinity of the Copper Cliff and Murray mines and the area intervening, many of these dykes have been encountered, and it has been found possible over this limited area, to accurately determine and map their dimensions and direction, and although the prevailing direction is perhaps northwest and southeast, many of them occupy fissures with courses very widely divergent.

Dīabase at Copper Cliff resembles finer grained varieties of norite.

Significance of discovery of original quartz in diabase, and olivine in norite.

Diabase contains both nickel and copper.

Mode of occurrence of diabase dykes.

No local enrichment of ore bodies in vicinity of these dykes.

No constant direction.

MINERALS ASSOCIATED WITH THE NICKEL AND COPPER OF THE SUDBURY MINING REGION.

PYRRHOTITE AND CHALCOPYRITE.

Ore bodies manil composed of pyrrhotite and chalcopyrite.

The ore bodies, with which the nickel and copper are immediately associated, consist essentially of pyrrhotite ($Fe_8\ S_9$) which is by far the most predominant constituent, and chalcopyrite ($Cu\ Fe\ S_2$) usually in much smaller amount, and a varying proportion of gangue, consisting mainly of the associated eruptive or its constituent silicates. The nickel present in the ore bodies is not, as so many have supposed, an essential constituent of the pyrrhotite, isomorphously replacing an equivalent amount of iron, but is mainly present, at least, as a distinct and magnetically separable nickel-iron-sulphide known as pentlandite. This mineral is, as a rule, very intimately associated with the pyrrhotite, but occasional hand specimens from the lower levels of the old Copper Cliff mine, show a rather intimate association of nearly pure pentlandite and chalcopyrite. The pyrrhotite and chalcopyrite will be described more fully in that portion of the bulletin, dealing with the composition of the ore bodies.

Nickel always present as pentlandite.

PENTLANDITE.

Pentlandite usually very finely disseminated through pyrrhotite.

This mineral is usually very intimately associated with the pyrrhotite, and is so finely disseminated through the mass of this mineral, that a separation can only be effected by very fine grinding. Though pentlandite itself is feebly magnetic, and in finely powdered form is attracted by an ordinary hand magnet, advantage is taken of the great difference in the magnetism of these two minerals, to effect their separation. It requires repeated trials to eleminate the last traces of the pyrrhotite, but this has been successfully done by Penfield, Browne and Dickson, and their analyses which are quoted give all necessary details of the chemical composition of this mineral, showing it to be very uniform over the whole district. It is essentially the same as the original pentlandite (eisennickelkies), analyzed by Scheerer, but contains more nickel, and less iron and sulphur. Sometimes as at the Worthington mine, it occurs in tolerably large pieces, which can be readily distinguished from the enclosing pyrrhotite, but even these contain a considerable amount of disseminated pyrrhotite, so that material thus secured, rarely assays over 30 per cent of nickel. The mineral is very abundant at the Creighton mine, and can be readily recognized on account of its perfectly developed, octahedral parting. It is somewhat paler in co-

Successfully separated magnetically by Penfield Browne and Dickson.

Péntlandite in large and rather pure fragments at Worthington and Creighton mines.

Colour of pentlandite.

Physical characters of pentlandite.

lour than the pyrrhotite, varying from steel-gray to silver-white, and almost invariably breaks with flat surfaces, which are planes of parting, parallel to the octahedron. The mineral, however, in freshly broken material, cannot readily be distinguished from the equally fresh pyrrhotite, especially if the planes of parting are imperfectly developed. Exposure to the weather brings about a rapid change in colour to a peculiar pale bronze, yellow, which is very characteristic and quite distinct from the pyrrhotite.

Chemical analyses by Penfield, Dickson and Browne.

The material obtained by Penfield (¹) was crushed and sifted to a grain of from 1-2 mm. in diameter, and the pyrrhotite was extracted by means of an ordinary magnet. The pentlandite, for analysis, was further carefully selected by hand-picking.

Similar, preliminary, careful preparation of material was used by Mr. C. W. Dickson (²). The following are the analyses :—No. 1 (Penfield); 2-4, (Dickson); 5-9, (Browne) (³). Analyses 5-7 inclusive, are stated to contain some pyrrhotite, as fine dust. Analyses 10 and 11, are by Scheerer (⁴) of the pentlandite from Lillehammer. Analysis No. 2, is from Creighton mine; No. 3, Worthington mine; No. 4, Frood mine; No. 5, Copper Cliff mine; No. 6, Stobie mine; No. 7, Evans mine; No. 8, Copper Cliff mine (hand-picked); No. 9, Evans mine (hand-picked).

	1	2	3	4	5	6	7	8	9	10	11
Ni	34·23	34·82	33·70	34·98	35·05	34·70	34·12	35·00	34·90	18·35	21·07
Co	0·85	0·84	0·78	0·85							
Fe	30·25	30·00	29·17	30·04	29·80	29·90	29·95	30·30	29 60	42·70	40·21
S	33·42	32·90	32·30	33·30	34·35	33·90	35·43	33·50	33·55	36·45	36·64
Cu										1·16	1·78
Gangue	0·67										
	99·42	98·56	95·95	99·17	99·20	98·50	99·50	98 80	98·05	98·66	99·70

Ratios of constituents of pentlandite.

The ratios in Prof. Penfield's analysis are S : (Fe + Ni) = 1·044 : 1·047, almost 1 : 1, or that of a normal sulphide (Ni + Fe) S. The ratio of the Fe : Ni is 1 : 1·32, while in that from Lillehammer, it is about 2 : 1. Dickson remarks that the ratio of the (Ni & Fe) : S varies from 10·91 : 10 to 11·07 : 10, and points out that this ratio 11 : 10 is not accidental, but constant for all analyses of pure material. He therefore suggests, that the formula for this mineral be written $(Fe + Ni)_{11} S_{10}$ which seems rather clumsy and an unnecessary refinement of expression of material, which, even when every precaution is taken, is

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(1) Amer. Jour. Sc. (3rd Series) Vol. XLV, 1893, pp. 493-494.

(2) Trans. Amer. Inst. Min. Eng., Albany Meeting, February, 1903.

(3) Eng. & Min. Jour., December, 2nd 1893, Vol. LVI, p. 566.

(4) Dana, System of Mineralogy, 6th Ed. 1892, p. 65.

still not absolutely pure. The formula of the Lillehammer pentlandite is given as 2 Fe S+Ni S. The ratio of nickel to cobalt in the Sudbury pentlandite varies, running from 40 to 42 : 1, is worthy of remark, as this proportion is almost identical with that found in the ore bodies.

Composition and magnetic separation of sulphides from Creighton mine.

A magnetic separation of the nearly pure sulphides, forming the ore from the Creighton mine, was made, by means of the Wetherill separator, the material thus used being crushed to different degrees of fineness, and graded by means of sieves. The original product showed an assay value of 1.20 per cent of copper, and 4.87 per cent of nickel, with 2.49 per cent of insoluble matter. The very fine material gave the cleanest separation, and some of that which passed through a 100-mesh sieve, was divided into three products which may be distinguished from one another as strongly magnetic, feebly-magnetic and non-magnetic. The feebly magnetic product showed the presence of 30.41 per cent of nickel, and the non-magnetic 30.36 per cent of nickel. A complete analysis, and an adjustment of the various constituents, showed that the feebly magnetic portion consisted of chalcopyrite and pentlandite, in the proportion of 1 : 21, while the non-magnetic product showed these same minerals present, in the proportion of 1 : 7.

PYRITE.

Pyrite at Elsie mine.

Nickel bearing pyrite at Copper Cliff mine.

Nickel-bearing pyrite from Century Copper mine.

Chemical analysis of true nickeliferous pyrite from Murray mine by Dr. Walker.

A sulphide which presents all the ordinary physical characters of pyrite, such as hardness, specific gravity, colour, lustre, and magnetism, is by no means uncommon in most of these deposits, and can generally be found when a special search is made for this mineral. Large cubical crystals of pyrite, are mentioned by Dr. Coleman, (1) as occurring in fissures, with quartz and calcite, at the Elsie mine, but the assay of one of these showed no nickel. Dickson mentions the fact that a number of his samples from the Copper Cliff mine, were associated with secondary quartz, calcite and millerite. Pyrite was also noticed occurring with pyrrhotite, chalcopyrite and danaite, at the Century Copper mine on the north half of lot 4, con. IV., of the township of Graham. A determination by Mr. F. G. Wait of the Geological Survey, showed 0.49 per cent of nickel, with a trace of cobalt. Dr. Walker (2) found what he regards as a true nickeliferous variety at the Murray mine, and has published a full description and analysis of the specimen. The following is the analysis under I, and if the mineral be considered as pyrite, in which part of the iron is replaced isomorphously by nickel, the explanation is given under II and III.

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(1) Ann. Rep. Bur. of Mines, Ont. 1903 p. 281.

(2) Amer. Jour. Sc. Vol. XLVII, 3rd Series, April 1894, pp. 312-314.

I		II			III	
Nickel	4·34	Nickel		4·34	NiS_2	9·12
Iron	39·70	Sulphur	49·31	4·78		
				44·53	FeS_2	83·49
Sulphur	49·31	Iron	39·70	38·96		
				·74	Fe_3O_4	1·02
Moisture	·10	Oxygen (calculated).		·28		
Copper	traces	Water..				·10
Insoluble	5·76	Insoluble				5·76
Arsenic	none					
					Total	99·49

Nickel bearing pyrite from Gertrude mine.

A peculiar, grayish-green, bronze-coloured, non-magnetic mineral, was found by Mr. McVittie on the location where the Gertrude mine now is. The mineral occurred massive, with small crystals of magnetite, and specks of chalcopyrite disseminated through it ,in a streak about six inches wide, adjoining the granite. An analysis of the mineral, after removing the magnetite, gave Mr. Mickle (¹) the following results under I, while under II, is given the proportions, omitting the insoluble matter and recalculating to 100.

Chemical analysis of nickeliferous pyrite from Gertrude mine by Mickle.

	I	II
Iron	37·28	41·48
Sulphur	46·54	57·79
Nickel	5·95	6·62
Copper	0·10	0·11
Insol.	9·66	.....
Total....	99·53	100·00

Mr. Mickle regards this as an agregate made up of pyrite, millerite and chalcopyrite, the composition, as given above, practically agreeing with such a mixture. A very similar compound is found at the old Beatrice mine (Davis property), on lot 1, con, III., of the township of Blezard. After an analysis of this material, Dr. Emmens (²) decided, that the mineral was a new nickel-iron-sulphide, and proposed for it the name 'Whartonite'. The mineral is not homogeneous and is very evidently a mixture. It has a peculiar bronze-yellow colour, is cellular, the cavities being lined with minute cubical crys'als, with an intermediate, finely, granular material. It was usually referred to by

Whartonite not a mineral species but a nickel bearing pyrite.

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(1) Ann. Rep. Bur. of Mines, Ont., 1903, p. 282.

(2)Ann. Rep. Bur. of Mines, Ont., 1892, p. 170.

the miners as 'matte', on account of the resemblance to this artificial product. The chemical analysis by Emmens showed it to contain (¹)·

Nickel	5·40
Iron	42·90
Sulphur	45·00
Insoluble	4·80
Total	98·10

MARCASITE.

Distinguishing characters of marcasite.

The mineral thus designated, is distinguished from pyrite, chiefly by its silver white colour, which even weathering only deepens slightly to a very pale, bronze-yellow. Samples of such material, submitted to Prof. Penfield, by Mr. C. W. Dickson, were considered by him as massive marcasite. The analyses conform to the formula, FeS_2 and show the presence of from 2 to 4 per cent of nickel, probably as pentlandite. Dr. Walker mentions the occurrence of marcasite, in the midst of the usual sulphides at the Murray mine, but assays of this material failed to show the presence of any nickel. Perhaps the most noted specimens which may be included under this name, are those for which the name 'blueite' was proposed by Dr. S. H. Emmens (¹). The mineral has a metallic, somewhat silky lustre, while the colour is pale olive-gray inclining to bronze. The type specimens came from the Gersdorffite mine (lot 12, con. III., Denison), which, at the time, was worked under option, by the Emmens Metal Company. The mineral also occurs on the lot to the south (lot 12, con. II.,) as, well as at the Totten mine (lot 1, con. II., Drury), and at the Worthington mine (lot 2, con II., Drury). Dr. Emmens' analysis showed the presence of 3·5 per cent of nickel with 38·8 per cent of iron, and 5·4 per cent of insoluble matter, but the sulphur 52·3 per cent, calculated by difference, is evidently too high. At the Gersdorffite mine, the nickeliferous marcasite occurs in association with niccolite, gersdorffite, pyrrhotite and chalcopyrite, in a small quartz vein, cutting a hornblende schist.

Marcasite without nickel at Murray mine.

Blueite of Emmens is nickeliferous marcasite.

Chemical composition of blueite.

At the Worthington and the Totten mines this very white nickel ore occurs in the form of circular or oval patches, which are very conspicuous, embedded in the pyrrhotite, chalcopyrite, and associated with rocky matter. An assay of a specimen from the Worthington mine, by T. L. Walker, showed the presence of 4·5 per cent of nickel. A specimen was also sent to Prof. F. W. Clarke, chief chemist of the

Chemical analysis of nickeliferous marcasite by Dr. Hillebrand

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(1) Ann. Rep. Bur. of Mines, Ont., 1892, p. 170; also Jour. Am. Chem. Soc. Vol. XIV. No. 7.

(1) Jour. Am. Chem. Soc., Vol. XIV., No. 7; also Ann. Rep. Bur. of Mines, Ont., 1892, p. 168

U.S., Geological Survey, and an analysis of this ore was made by Dr. W. F. Hillebrand, his results being reported as follows (1)

Iron	38·36
Nickel	4·57
Manganese	0·10
Sulphur	45·11
Sulphuric acid	0·95
Carbonic acid	1·49‡
Calcium oxide	1·91
Magnesia	0·41
Insoluble	4·80
Water at 100° C.	0.55
Water combined	?
Loss and oxygen	?
Total....	98.25

Probable mixture of marcasite and pentlandite.

A consideration of the above analysis, shows that it agrees very closely with the assumption that the nickel is present in the form of pentlandite, disseminated through the marcasite. Prof. Clarke, in his letter, states. 'It seems to me that the material is a mixture, not a definite species. Your Sudbury minerals deserve an exhausive study, and the work would be well repaid.'

MILLERITE.

Millerite probable source of some of the nickel.

The simple or normal sulphide of nickel is occasionally met with in some of the mines, and may be the source of some of the nickel of these deposits. Agreeably with its formula NiS, this mineral should contain, when pure, 35.3 per cent of sulphur and 64.7 per cent of nickel. Undoubted slender crystals of millerite were found at the Copper Cliff mine, in workings 150 feet below the surface. Another specimen containing this mineral, associated with pyrrhotite, was obtained at the Beatrice mine, on lot 1, con. III., of Blezard township. Dickson mentions having found 'small bunches of hair-like crystals of this mineral, in the cavities of some radiating pyrite, mixed with calcite'. He regards the millerite as undoubtedly secondary, and probably derived from preexisting pentlandite.

Millerite at Copper Cliff and Beatrice mines.

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(1) Ann. Rep. Geol. Surv. Can., Vol. V., 1890-91.. Part S.S., p. 116.

‡ Calulated on the supposition that all the calcium exists as carbonate.

POLYDYMITE.

Association of polydymite at Vermilion mine.

This mineral occurs in association with chalcopyrite, chalcocite, pyrrhotite and pyrite at the Vermilion mine, lots 5 and 6, con IV., of the township of Denison. It is steel-gray, massive, and exceedingly alterable in the air. It has a specific gravity of 4.5. An analysis of carefully selected material, gave Clarke and Catlett the results under I, (1) A good sample of the Vermilion ore, analyzed by Mr. Browne, after deducting 1.5 per cent of silica, gave the results under II, evidently impure polydymite. (2)

Chemical composition of polydymite.

	I	II
Nickel	41·96	36·85
Iron	15·57	18·70
Sulphur	40·80	38·43
Copper	0·62	4·47
Silica	1·02	
Totals..	99·97	98·45

Formula of polydymite.

These figures give approximately the formula Ni_3FeS_5. Neither cobalt nor arsenic could be detected. If we deduct silica, together with the copper reckoned as admixed chalcopyrite, and recalculate the remainder of the analysis under I, to 100, we get the following figures

Nickel	43·18
Iron	15·47
Sulphur	41·35
Total...	100·00

In short, the mineral has the composition of Ni_4S_5 with about one quarter of the nickel replaced by the iron, which agrees with Laspeyres, polydymite, of which it is doubtless a ferriferous variety. The polydymite from which the above was selected, came from a mass in which an average of 35.39 per cent of nickel and 5.20 per cent of copper had previously been found.

Analysis of polydymite and associated minerals by Johnston.

A specimen of the so-called polydymite, was presented to the writer by Mr. F. L. Sperry, at one time chemist of the Canadian Copper Co. The mineral at the time was known to be impure, but was the best sample which could be secured for the museum. The material was mainly polydymite, in a gangue composed of diorite and small quantities of quartz. Carefully selected material—which however it was found still contained a little intermixed gangue and chalcopyrite—was found, by Mr. R. A. A. Johnston to contain 40·80 per cent of nickel with no cobalt.

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(1) Amer. Jour. Sc., Vol. XXXVII, 1889, p. 372-374.

(2) Eng. and Min. Jour., Dec. 2, 1893. Vol. LVI, p. 566,

SPERRYLITE.

Discovery of sperrylite

Examination and description by Wells and Penfield.

Sperrylite was first found at the Vermilion mine in the gossan or loose material, and was named after Mr. Francis L. Sperrry of the C. C. Co. by Profs. Horace L. Wells and S. L. Penfield, of the Sheffield Scientific School, who examined and described this new species(¹). The material as received, consisted of a heay, brilliant sand, composed largely of the sperrylite, but intermixed with this, a considerable number of fragments of chalcopyrite, pyrrhotite and some silicates could be seen. After the material was purified, it was found to contain some transparent grains which proved on examination, to be oxide of tin or cassiterite ($Sn\,O_2$).

Physical characters of sperrylite.

Chemical composition.

Sperrylite is isometric, simple cubes are common, octahedrons are exceptional, while the majority of the crystals are combinations of the cube and octahedron. Hardness is between six and seven, as it scratches felspar, but not quartz. The specific gravity is 10,602. The crystals have no distinct cleavage, but are very brittle, and break with an irregular, probably conchoidal fracture. The chemical composition, according to the mean of two analyses, was as follows :—

Arsenic	40·98
Antimony	0·50
Platinum	52·57
Rhodium	0·72
Palladium	trace
Iron	0·07
Cassiterite or oxide of tin	4·62
Total......	99·46

Formula.

The composition is therefore represented by the formula $PtAs_2$, a small portion of the platinum and arsenic being replaced respectively by rhodium and antimony. The colour of the mineral was nearly tin-white, or about the same as metallic platinum. The fine powder is black. Nearly all the grains showed extremely brilliant, crystal faces, though most of the crystals were fragmentary in size, usually $\frac{1}{50}$ to $\frac{1}{500}$th of an inch in diameter.

Size of grains.

No iridium present.

The presence of an appreciable amount of iridium was expected by Professor Wells, but careful search failed to reveal even traces of this element.

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(1) Amer. Jour. Sc. Vol. XXXVII, 1889, pp. 67–63

Sperrylite is regarded as the source of the metals of the platinum group, which are invariably present in appreciable amounts in the bessemer matte, assays of the Copper Cliff and Victoria mines mattes showing from 0·4—0·5 oz. per ton. Wherever occurrences of this mineral have been examined, it is directly and intimately associated with the chalcopyrite, so that, mattes rich in copper, contain a large amount of platinum, while those containing very little copper, show a correspondingly small amount of platinum. In Dr. Walker's (1) analysis of the bessemer matte from the Murray mine, the presence of iridium and osmium is noted in almost equal amounts, but in Prof. Wells' analysis, as noted above, these metals were not detected. Baron von Foullon concludes from the absence of these elements, that there is another mineral present, which contains the iridium, but although this is possible, Dr. Walker considers that a more likely explanation is that, in some cases, part of the platinum in sperrylite, is replaced by the elements iridium and osmium.

Source of platinum in the matte.

Iridium and osmium sometimes replaces platinum.

NICCOLITE.

This mineral, in intimate association with gersdorffite and with variable quantities of intermixed pyrrhotite, chalcopyrite and pyrite, has been found in connection with the occurrence of two small 'stocks' or intrusions of quartz-mica-diorite (altered norite), in the township of Denison. This diorite forms two small hills, which rise above the surrounding country, which is underlaid by the slaty variety of the tuffs or greywackes, these rocks surrounding the diorite on all sides. One of these masses, known as the Macdonell or Gersdorffite mine is situated in the southeastern corner of lot 12, con. III., of Denison while the other, constituting what is known as the Hiram Robinson property, is on the northeastern corner of the west half of lot 12, con. II., of the same township. The country rock, in the immediate vicinity, is usually a more or less schistose diorite or hornblende schist, produced by the shearing of the more massive diorite, of which most of the hill is composed. The rock is made up, chiefly, of irregular crystals of hornblende, closely aggregated together, the few and small remaining interspaces being occupied by quartz and plagioclase. At the Gersdorffite mine, from which the first and finest specimens of this mineral, and the associated gersdorffite were obtained, they occur in a small vein, interfoliated with a chloritic actinolite schist, at the north side of the small area of diorite, shown on the map. The vein consists mainly of quartz, with a very small amount of felspar and calcite, with

Geological associations of niccolite.

Localities where found.

Mineral constituents of associated rocks.

Constituents of vein containing niccolite.

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(1). Amer. Jour. Sc., Vol. 1, 1896, p. 112.

Composition of niccolite.

Analysis of niccolite and gersdorffite by Mr. Walker.

grains and small disseminated masses of the sulphides already mentioned, the most abundant and conspicuous being the niccolite and especially the gersdorffite. No analysis of the niccolite was made. This, when pure, is represented by the formula Ni As = arsenic 56·1, nickel 43·9 = 100·0. It usually contains a little iron and cobalt, also sulphur, while sometimes part of the arsenic is replaced by antimony. The mineral occurs massive, and the peculiar pale, copper red is quite distinctive. A sample containing niccolite and gersdorffite was submitted by the writer to Mr. T. L. Walker who found them too intimately associated to separate for analysis. He therefore made an analysis of the two minerals together, which resulted as follows : (1)

Nickel	20·87
Cobalt	0·64
Copper	trace.
Iron	2·43
Sulphur	10·60
Arsenic	26·04
Silica	26·70
Alumina	5·43
Magnesia Lime Soda	7·29
Total........	100·00

GERSDORFFITE.

First recognition of gersdorffite.

This mineral was first recognized in a small sample brought to the Geological Museum, in 1891, by Mr. Eagleson, who had obtained the specimen from Mr. Dan. O'Connor, of Sudbury, the owner of the Gersdorffite mine, where it had been found. The particulars of the association of the mineral have already been described under niccolite. When pure, the mineral is essentially a sulph-arsenide of nickel, with the formula $NiAsS$ or NiS_2, $NiAs_2$ = sulphur 19·3, arsenic 45·3, nickel 35·4 = 100·0. Iron replaces the nickel, often to considerable amount, also sometimes cobalt. The following is the description of the specimen collected by the writer in 1891, prepared by Dr. Hoffmann and Mr. R. A. A. Johnston. (2)

Physical characters of gersdorffite.

Structure, for the most part lamellar, but occasionally granular, a few minute, fairly well developed crystals exhibiting the forms of the octahedron and cubo-octahedron, with the faces of the octahedron predominating, were also observed. Colour, steel-gray, here and there tarnished blackish. Specific gravity (after correction for a little included quartz) at 15·5°C., 6·231.

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(1) Ann. Rep. Geol, Surv, of Can., Vol. V. 1890-91, Part SS. p. 118.

(2). Ann. Rep. Geol. Surv. Can., Vol. V, 1890-91, Part R, p. 22.

Chemical analysis of gersdorffite by Johnston.

The material upon which the analysis was conducted, although selected with all possible care, and, so far as could be seen, apparently pure, nevertheless contained, it was subsequently found, a very appreciable amount of quartz. Its analysis afforded Mr. R. A. A. Johnston the results given under I. Deducting the gangue (silica), and recalculating the remaining constituents to one hundred parts, we obtain the figures given under II.

	I	II
Arsenic	40·31	46·96
Sulphur	14·34	16·71
Nickel	22·50	26·32
Iron	6·78	7·90
Cobalt	1·73	2·01
Copper	0·09	0·10
Gangue (quartz)	13·55	.....
Total..........	99·39	100·00

This mineral had not previously been identified as occurring in Canada.

MORENOSITE.

Composition of morenosite.

This mineral, which is also known as "Nickel vitriol" is a hydrous, nickel sulphate ($Ni\ SO_4 + 7\ H_2O$) = sulphur trioxide 28·5, nickel protoxide 26·6, water 44·9 = 100·0. 'It occurs as a greenish-white and pale apple green incrustation on associated gersdorffite, niccolite, chalcopyrite and pyrrhotite at the Macdonell or Gersdorffite mine (lot 12, con. III, of Denison); also but more sparsely as a greenish-white incrustation on some of the nickeliferous ore of the Worthington mine (Lot 2, con II., Drury)'. (1) It has also been noticed at the Wallace mine on Lake Huron.

Localities where morenosite is found.

ANNABERGITE.

Some specimens of gersdorffite, which had been in the drawers of a mineral cabinet for about a couple of years, were found to have undergone a partial decomposition, with the formation of hydrous nickel ar-

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(1) Ann. Rep. Geol. Sur. Can., Vol. VI, 1892-93, Part R, p. 27.

Composition and physical characters of hydrous nickel arsenate.

senate. The material which came from the Gersdorffite mine, (lot 12, con. III., Denison), consisted of gersdorffite, with a few scattered particles of chalcopyrite. The nickel arsenate, which occurred both lining and filling cavities in the gersdorffite was, in the former case, in the form of botryoidal, globular, or mammillary crusts of a greenish-yellow colour, pale grass-green, and honey-yellow to brownish colours, and exteriorly of a sub-vitreous to vitreous lustre, whilst that filling the cavities was compact and amorphous, texture colloid, of a greenish-yellow colour and waxy lustre, also occasionally, but more rarely, earthy, chalk-like and dull. (1)

DANAITE, (COBALTIFEROUS ARSENOPYRITE).

Theoretical composition of cobaltiferous arsenopyrite or danaite.

This mineral is a sulph-arsenide of iron (Fe As S), with part of the iron replaced by cobalt. Agreeable with the formula given above, it should contain, theoretically, arsenic 46·0, sulphur 19·7, iron 34·3 = 100·0. It is not abundant in the Sudbury district, and has only been recognized as occurring in two localities, and in both of these places it is found in association with the older diorites and hornblende schists. The first place in which it was found is on the north half of lot 6, con III., of the township of Graham, this lot forming a portion of what is known as the Russell location or property.

Associations of danaite.

Physical characters.

The mineral is massive, with a steel-gray colour. Intermixed with it, were small quantities of white, translucent quartz, some pyrrhotite, a little galena and a trifling amount of chalcopyrite. The specific gravity at 15·5° C. = 5·988.

Analysis of danaite by Johnston.

An analysis by R. A. A. Johnston (2), of carefully selected material, is given under I. Deducting the gangue or silica, and recalculating to 100 we obtain the results under II.

	I	II
Arsenic	40·16	42·22
Sulphur	17·92	18·84
Iron	31·69	33·32
Cobalt	3·89	4·09
Nickel	0·88	0·93
Antimony	0·57	0·60
Gold	trace.	trace.
Gangue (quartz)	4·77	
Totals.........	99·88	100·00

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(1) Ann. Rep. Geol. Sur. Can., Vol. VI, 1892-93, Part R, p. 27.

(2) Ann. Rep. Geol. Sur. Can., Vol. V, 1890-91, Part R, p. 19.

This mineral also occurs in considerable quantity on the N. ½ lot 4, con. IV., of the township of Graham, at a deposit which was being worked for copper, and known as the Century Copper mine. It is present in intimate association with pyrrhotite, chalcopyrite and pyrite, abundantly disseminated through a hornblende and biotite schist, and also through a pale grayish quartzite, which is embedded in the hornblende schist.

Danaite of Ceutury Copper mine.

SMALTITE.

This mineral so far as known, is rare in the Sudbury district, although it occurs in large masses in the Temagami region, to the northeast. It is a cobalt diarsenide, $CoAs_2$=arsenic 71·8, cobalt 28·2=100·0. This mineral was observed by Mr. E. B. Kenrick, of the Geological Survey of Canada, in the form of minute crystals, with well marked octahedral cleavage, in association with chalcopyrite, from the township of McKim. (¹)

Recognition of smaltite from McKim by Kenrick.

GALENA.

This mineral has been found at all the mines, wherever search was made for it. It is the common sulphide of lead PbS=sulphur 13·4, lead 86·6,=100.0; usually contains a little silver. It generally occurs in thin seams penetrating the other sulphides. It may be the source of much of the silver found in all the mattes produced from the Sudbury ores. It shows the usually bright lead-gray colour, with distinct cubical cleavage. No analysis was made of this mineral in immediate association with the ore bodies.

Galena always present in association with Sudbury ore bodies.

CHALCOCITE.

This mineral, also known as copper glance, has only been described as occurring at the Vermilion mine, in Denison township. Its occurence at this place is noticed by Mr. Johnston, in a specimen which was given to the writer by Mr. F. L. Sperry. This specimen consisted of chalcocite and chalcopyrite, through which was disseminated some polydymite. Some of the fragments were coated with green carbonate of copper. Mr. Johnson found that the specimen contained 9·40 per cent of nickel with no cobalt. No chemical analysis of the chalcocite was made.

Chalcocite in association with polydymite at Vermilion mine,

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(1) Ann. Rep. Geol. Sur. Can., 1886, Part I, p. 13.

BORNITE.

Bornite occasionally occurs according to Dickson.

This mineral is mentioned as occasionally seen by Mr. C. W. Dickson. Some of the chalcopyrite, obtained at the Vermilion mine, which was greatly weathered, has a general resemblance to this mineral. No undoubted bornite was, however, noticed by the writer.

MAGNETITE.

Titaniferous magnetite an invariable constituent of the norite.

Magnetite of Murray mine.

Mass of magnetite weighing 5 tons found at Clarabelle mine.

This mineral is an invariable constituent of the norite, and is always more or less titaniferous. It is generally disseminated in minute grains through the ore bodies, but, as a rule, in very subordinate amounts. Occasionally, small masses of titaniferous magnetite are associated with the pyrrhotite, and an analysis of such a mass, from the Murray mine, gave Dr. Walker, (¹) 18·34 per cent of titanic acid. The largest mass yet noticed was recovered from the workings of the Clarabelle mine, where, according to Capt. McArthur, about five tons were found enclosed in the sulphides. This magnetite is readily attracted by the magnet, and contains grains of pyrrhotite and chalcopyrite, as well as small portions of a green silicate. (²)

CASSITERITE.

Cassiterite occurs associated with sperrylite.

The purified material from which the analysis of sperrylite was made by Professor Wells, of Yale University, contained as stated, 4.62 per cent of oxide of tin, in the form of minute transparent grains. These were carefully examined and pronounced to belong to the species cassiterite.

NATIVE COPPER.

Native copper found at Vermilion and Copper Cliff mines.

Dendritic or leaf-like forms, are occasionally met with, as at the Vermilion mine, where a few specimens of chloritic schist were obtained, showing native copper, developed along the planes of cleavage. L.P. Silver has a specimen of the diorite, obtained from the twelfth level of the Copper Cliff mine, showing a good deposit of leaf copper, which he considers must have been formed, by the reduction of the chalcopyrite, by reducing solutions leaching through the rock (³).

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(1) Quart. Jour. Geol. Soc. Lon., Vol. LIII, Feby., 1897, p. 52.

(2) Ann. Rep. Bur. of Mines, Ont., 1903, p. 281.

(3) Jour. Can. Min. Inst., Vol. V, 1902, p. 536.

NATIVE GOLD.

Native gold at Vermilion mine.

Samples of the ore obtained from the Vermilion mine contain appreciable quantities of native gold, and specimens may be obtained from this mine, showing abundantly disseminated grains and strings of gold, often of large size. All of the mattes produced from the Sudbury ores contain gold, the percentages of this metal, varying in the bessemer matte, from strong traces to 0.3 oz. per ton. The average amount would be about 0.15 oz. of gold per ton, although Silver (¹) reports having found 0.75 oz. of gold, in a matte which contained 39.64 per cent of nickel and cobalt, and 42.75 per cent of copper.

All the mattes contain appreciable quantities of gold.

GRAPHITE.

Graphite notice by Dr. Coleman.

Dr. Coleman (²) reports having found a few scales of graphite, in the country rock, occurring on the dump at the Lady Macdonald mine.

CUBANITE.

Cubanite, one of the products of roasting noticed by Browne.

David H. Browne (³) for some time chemist to the Canadian Copper Co., at Copper Cliff, found this mineral, which is represented by the formula $Cu\ Fe_2\ S_4$ = sulphur 35.4, copper 23.3, iron 41.3 = 100.0, in the roast heaps, being one of the products formed during the roasting.

In addition to the above mineral varieties mention may be made of the fact that quartz, calcite, dolomite and ankerite are found in association with the massive sulphides, but these minerals are relatively very unimportant, and even at such deposits as the Victoria mines considerable quartz has to be added to the furnace charges on account of the basicity of the associated rocks. Nearly all of the gangue occurs as intermixed norite or diorite.

Composition of the ore-bodies.

Ore bodies made up principally of pyrrhotite and chalcopyrite.

The ore bodies, with which the nickel and copper are immediately associated, consist essentially of a mixture of sulphides, in which pyrrhotite (Fe_8S_9), is, by far, the predominant constituent; chalcopyrrite is almost invariably present, and usually in considerable amount, although proportionately much less than the pyrrhotite. It has been conclusively proved by means of the magnetic separations carried on by Browne,

Proved conclusively that the nickel occurs in the form of pentlandite.

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(1) Jour. Can. Min. Inst., Vol. V, 1902, p. 534.

(2) Ann. Rep. Bur. of Mines, Ont., 1903, p. 284.

(3) Ann. Rep. Bur. of Mines, Ont., 1903, p. 284.

Dickson and the writer, that the nickel present in these ores is all contained in the pentlandite, although the first mentioned authority is still inclined to the belief, that the small amount retained by the magnetic portion or pyrrhotite proper, occurs in part, at least, as an essential constituent of the pyrrhotite. This pentlandite is usually very finely and uniformly distributed throughout the whole mass, although in certain mines as the Creighton, Copper Cliff, Evans and very noticeably the Worthington mine, it occurs in spots and patches, often as much as half an inch to an inch, or even more, in diameter, of fairly pure material. The relative abundance of this nickel-iron-sulphide, determines the richness, or otherwise, of the containing deposit. Pyrite also contributes to the formation of these deposits, and much of it is nickeliferous. Present opinion varies somewhat in regard to the form in which the nickel is present in this compound, Dr. Walker's researches tending to prove, that this element replaces isomorphously an equivalent amount of iron in chemical combination, while others regard intermixed pentlandite as the source of the nickel. Certain other sulphides of nickel already mentioned and described, also contribute to the unusual richness of these deposits, but these are relatively much less important, and many of the occurrences, where such minerals are present, are, so far as known, of no commercial importance. A varying amount of gangue, usually of the associated eruptive, but occasionally also of the older green schists, greywackes and even quartzite, is always present. The percentage of such intermixed rocky matter is sometimes unusually large, as in certain portions of the Elsie and Murray mines, where material has been used in large amount, which consists of sulphides and rock in about equal proportion, while, in other instances, as at the Creighton and Victoria mines, the sulphides are so pure and massive that large quantities of associated norite have to be added to the furnace charge to act as a flux. Magnetite, and certain of the silicates, peculiar to the norite, usually more or less decomposed, such as hornblende, actinolite, serpentine or chlorite are almost always present. A comparatively small amount of quartz, calcite, dolomite and very occasionally crystals of tourmaline molybdenite and apatite are also found.

Pentlandite usually very finely and evenly distributed.

Occasionally occurs in large spots and patches.

Nickel bearing pyrite.

Walker's belief that the nickel in pyrite isomorphously replaces iron.

Other sulphides occur but relatively unimportant.

Presence and abundance of rocky admixture or gangue.

Other impurities present in ore bodies.

The pyrrhotite and chalcopyrite, are not, as a rule, so intimately commingled as to form a homogeneous mass, but each may be described as occurring in pockets, spots, bunches or threads, in the other. The chalcopyrite is not so closely intermixed with the pyrrhotite but tends to isolate itself rather in patches or spots, usually enclosing, but occasionally enclosed by the pyrrhotite. It is sometimes possible to separate considerable masses of chalcopyrite, assaying over 30 per cent of copper, or pyrrhotite, that will only show traces of that metal. In practice, however, careful examination and trial have proved that the two minerals

Relation of sulphides to one another.

Sorting by hand not practicable.

are too intimately associated, to make sorting by hand, at all practicable. Although the chalcopyrite seldom occurs free from the pyrrhotite, large and massive deposits of the latter occur comparatively free from copper. The first ore shipped from the Gertrude mine, was so free from copper, that it was proposed to utilize it for the production of ferro-nickel, and this deposit was purchased by the Lake Superior Power Company, with this object in view. Analyses made of a large mass of the Creighton mine ore obtained near the surface, show the nickel to vary from 4.87 per cent to 5.31 per cent, with 0.72 per cent to 1.20of copper. The prevailing intimacy of association, however, of the pyrrhotite and chalcopyrite, will perhaps be better appreciated by mention of the fact that hand-picked specimens from the Evans, Stobie and Copper Cliff mines, collected and analyzed by Mr. Browne (1), showed the presence of from 13.86 to 15.71 per cent of copper with a sufficient quantity of intermixed pyrrhotite and pentlandite in the same, to assay from 1.28 to 2.47 per cent of nickel. On the other hand, selected nickel ore from Copper Cliff mine, with 8.12 per cent of nickel, contained only 0.80 per cent of copper, while similarly picked ore from the Evans mine containing 5.36 per cent of nickel showed the presence of only 0.49 per cent of copper. In certain of the deposits, as for instance, at the main shaft of the Victoria mines, the nickel and copper are almost identical in quantity, assays of a large number of samples, neglecting the insoluble matter, showing the presence of 3.66 per cent of each metal. At the Dominion, Murray and Elsie mines, the nickel is usually nearly double that of the copper. Thus, Mr. George Attwood, M. E., (2), at one time manager of the Dominion Mineral Company, under date of March 18th, 1891, stated that the 'kies' or metallic portion of the Blezard mine, averaged 4 per cent of nickel and 2 per cent of copper this result being the average of a large number of assays, as also of the practical working of the mine. About the same date, Mr. F. R. W. Daw, then manager at the Murray mine, stated that an average of the ore smelted at this mine, contained 1.5 per cent of nickel and 0.75 per cent of copper. Other assays of an average sample of ore from this mine, show 0.9 per cent of copper, with 1.5 per cent of nickel and 46 per cent of insoluble, or the equivalent of 1.66 per cent of copper and 2.76 per cent of nickel, in the pure sulphide material.

Masses of pyrrhotite occur comparatively free from chalcopyrite.

Partial analyses of the ores from some of the principal mines.

Nickel and copper nearly equal in amount at Victoria mines.

Nickel nearly double the copper at Dominion, Elsie and Murray mines.

Assays of 'kies' of Dominion mine.

Assays of ore from Murray mine.

The Gertrude and the Creighton mines, and especially the latter are deposits in which the nickel is often present in the ore in the proportion of 3 or 4 to 1. In the first years of the development of the mines of the Canadian Copper Company, the copper was greatly in excess of the nickel, and assays of specimens of raw ore, taken without selection

Preponderance of nickel in Gertrude and Creighton mines.

Copper greatly in excess in first years of operation of Copper Cliff mine.

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(1). Eng. and Min. Jour. Dec. 2nd. 1893, Vol. LVI, p. 566.

(2). Anu. Rep. Geol. Surv. Can., Vol. V, 1890-91, Part F., p. 52.

from these mines, showed a range in copper from 4·03– 9·98 per cent, with an average of 6·44 per cent, while the nickel, in the same specimens, varied from 1·12 per cent to 4·21 per cent, with an average of 2·38 per cent. This preponderance of the copper was maintained for some time, for an average of two samples of the blast furnace matte, taken 22nd February, 1889, and the 2nd March, of the same year, showed copper 26·91 per cent and nickel 14·14 per cent. About the same time, the Dominion Mineral Company produced mattes, containing from 18 to 20 per cent copper and 24 to 26 per cent nickel. At the present time, however, this condition of affairs is reversed, and two specimens of this matte, analyzed by Mr. Donald Locke, of this Department, showed 14·53 per cent and 14·69 per cent of copper with nickel 26·34 per cent and 28·17 per cent, respectively.

Proportion of nickel and copper in mattes from Dominion mine.

Analyses of matte Can. Cop. Co.

Percentage of nickel in the ore.

The nickel present in the pyrrhotite of the Sudbury District, varies usually from 2·25 per cent to 5·50 per cent, the lower figure being characteristic of such deposits as the Stobie, Murray and Elsie mines, while the latter is approached, and at times, exceeded by the ore of the Creighton, Victoria, Blezard, Copper Cliff and Evans mines. Small specimens are occasionally met with which contain as high as 30 per cent of nickel, as at the Worthington mine, but such material is only obtainable by careful hand-picking, at either the Worthington or Creighton mines. These ores contain appreciable quantities of cobalt, gold, silver, and metals of the platinum group. Cobalt is almost invariably present, but in most of the assays of the ores, which have been made, it is included with the nickel. The cobalt is usually very uniform in amount, in the proportion of 1 to 40 or 50 of the nickel present. The amounts of the rarer elements such as gold, silver and platinum are, usually so small, that the proportions of these can be best determined by analyses of the bessemer or higher grade mattes. Analyses of this product, which are available, containing about 80 per cent of combined nickel and copper, contain from 0·10 to 0·20 oz. of gold with an average of probably about 0·15 oz. to the ton of 2,000 lbs., although L. P. Silver (¹) obtained as high as 0·75 oz. of gold, in the high grade matte, of the Orford Copper Company, containing 39·64 per cent of nickel and cobalt and 42·75 per cent of copper. Locke, of the Geological Survey, shows that in this same matte, containing 40·37 per cent of nickel and 24·95 per cent of copper, only 0·10 oz. of gold per ton is present. In the matte produced by the Mond Nickel Company, containing 41·88 per cent of nickel and 37·37 per cent of copper, this same chemist found $\frac{1}{15}$ of an oz. of gold.

Amount of cobalt present.

Gold, silver and platinum are present in appreciable quantities.

Amount of gold present in mattes.

Amount of silver present in mattes.

The silver in the ore is still more variable, as Locke found 2·5 oz. to the ton, in the Orford Copper Company's matte, and 4·87 oz. to the

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(1) Jour. Can. Min. Inst., Vol. V, 1902, p. 534.
(2) Ann. Rep. Bur. of Mines Ont., 1900, p. 218.

ton, in the matte produced by the Mond Nickel Company. J. W. Bain's (²) analysis shows 5·1 oz. to be present in the Orford Copper Company's matte. L. P. Silver shows that 5·30 oz. are present in each ton, while Ulké states that 7 oz. of silver are present in this same matte. The platinum, as already mentioned, is directly associated with the chalcopyrite, and therefore, should be found in mattes which are relatively richer in copper. Locke found that the Orford matte contains, 0·44 oz. per ton of metals of the platinum group, while the Mond Nickel Company's matte, contains 0·4 oz. per ton of these same metals. Ulké mentions that the platinum and palladium, in about equal amounts, together made up about 0·50 oz. per ton, while L. P. Silver has secured the same result.

Percenaage of platinum in mattes.

Nickel and copper in Sudbury ores.

Nickel and Copper in Sudbury Ores.

—	Nickel.	Copper.	Total Nickel & Copper.	Authority.
	%	%	%	
1 Copper Cliff, Evans & Stobie mines	2·38	6·44	8·82	Can. Copper Co.
1*a* Copper Cliff mine, average 1890..	3·69	6·24	9·93	"
2 Copper Cliff mine (mixed ore).....	4·75	5·69	10·44	"
3 " (picked nickel ore)	8·12	0·80	8·92	"
4 " "	9·25	0·51	9·76	"
5 " "	11·00	0·00	11·00	"
6 " (picked copper ore)	2·74	14·13	16·87	"
7 " "	1·25	23·78	25·03	"
8 Evans mine (mixed ore)...........	4·00	2·60	6·60	"
8*a* Evans mine, average 1890.......	3·62	2·84	6·46	"
9 Evans mine (picked nickel ore)....	5·36	0·49	5·85	"
10 " "	9·02	0·00	9·02	"
11 " (picked copper ore).....	1·34	13·86	15·20	"
12 Stobie mine (mixed ore)..........	2·28	2·21	4·49	"
12*a* Stobie mine, average 1890........	2·00	1·99	3·99	"
13 Stobie mine (picked nickel ore)....	2·75	0·00	2·75	"
14 " "	2·99	0·37	3·36	"
15 " (picked copper ore)......	1·28	15·71	16·99	"
16 " "	0·64	24·23	24·87	"
17 No. 2 mine (picked nickel ore)....	4·70	0·38	5·08	"
18 " (picked copper ore)....	1·87	13·76	15·63	"
19 No. 2 Extension (picked ni. ore)...	4·32	0·35	4·67	"
20 No. 3 mine (Frood mine) (picked nickel ore)...................	4·85	0·42	5·27	"
21 No. 4 mine......................	4·33	1·39	5·72	"
22 "	4·15	2·49	6·64	"
23 Creighton mine.................	7·03	1·81	8·84	"
24 "	4·87	1·20	6·07	Geol.Surv. Dept.
25 "	5·31	0·72	6·03	"
26 Victor mine	3·50	4·50	8·00	Mond Nickel Co.
27 "	3·05	3·05	6·25	"
28 "	2·67	2·81	5·48	"
29 "	3·21	2·41	5·62	"
30 Worthington mine..............	3·00	3·00	6·00	C.W. Dickson.
31 " (picked ni. ore).	17·48	0·00	17·48	T. L. Walker.
32 Blezard mine (metallic portion)....	4·00	2·00	6·00	Dom. Min. Co.
33 Murray mine....................	1·50	0·75	2·25	H.H.Vivian&Co

EXPLANATIONS.

Analyses by F. L. Sperry.

1. Average of nine analyses, made by F. L. Sperry, of raw ore taken without selection, from the Copper Cliff, Evans and Stobie mines, of the Canadian Copper Co., in November, 1888. 1*a*. Average of Copper Cliff mine ore, for year 1890. (Ann. Rep. Geol. Surv. Can. Vol. V, 1890-91, Part F, p. 51.)

Analyses by D.H. Browne.

Analyses, 2, 3, 5, 6, 8, 9, 10, 11, 12, 13, 15, are by David H. Browne, chemist to the Canadian Copper Company. (Eng. and Min. Jour. Dec. 2nd 1893, p. 566).

Analysis 8*a*. Average of Evans mine ore for the year 1890. (Ann. Rep. Geol. Surv. Can. Vol. V, 1890-91, Part F, p. 51.)

Analyses by Canadian Copper Co.

Analyses, 4, 7, 14, 16, 17, 18, 19, 20, 21, 22, 23, 26, are from the catalogue of the mineral exhibit of Ontario, at the Pan-American Exposition of 1901. pp. 33 and 35.

Analysis 12*a*. Average of Stobie mine, for the year 1890. (Ann. Rep. Geol. Surv. Can. Vol. V, 1890-91, Part F, p. 51.)

Analyses by C. W. Dickson.

Analysis 30, is the result of a number of analyses of average samples, by Mr. C. W. Dickson, (Trans. Am. Inst. Min. Eng., Albany meeting, Feby., 1903).

Analyses by DonaldLocke.

Analyses 24 and 25, are by Mr. Donald Locke, of the Geological Survey Department, Ottawa, of material obtained within a few feet of the surface.

Analysis 27, is the result of an average of a large number of assays ot samples of raw ore, from the Victoria mines, as supplied to the smelter, by T. M. Paris, the chemist. The insoluble amounted to an average of 16·81 per cent.

Analyses by T. M. Paris.

Analysis 28, is the average of the raw ore, for July, 1902, by T. M. Paris, chemist to the Mond Nickel Company. Insoluble, 17·2 per cent.

Analysis 29, is the average of the raw ore for September 1902 by T. M. Paris, chemist to the Mond Nickel Company. Insoluble, 13·9 per cent.

Analysis by T. L. Walker.

Analysis 30, is the result of an analysis of the pyrrhotite, from the Worthington mine, which contained a large amount of pentlandite, by T. L. Walker. (Ann. Rep. Geol. Surv. Can., Vol. V, 1890-91, Part SS, p. 117.)

Analyses by Dominion Mineral Co.

Analysis 32, according to Mr. George Attwood, manager for the Dominion Mineral Company, is the average of the results of many hundreds of assays of the " kies " or metallic portion of the ore of the

Blezard mine, also the practical working of the mine on a large scale. (Ann. Rep. Geol. Surv. Can. Vol. V, 1890-91, Part F, p. 52.)

Analyses by H. H. Vivian & Co.

Analysis 33, is the average percentage of the ore smelted at the Murray mine, according to Mr. F. R. W. Daw, the manager for Messrs H. H. Vivian & Co. The "kies" or metallic portion of the Murray mine ore contains on an average of about 2·75 per cent of nickel and 1·65 per cent of copper.

NICKEL AND COBALT IN ORES FROM SUDBURY DISTRICT.

Determinations for nickel and cobalt in Sudbury ores by Dr. G. C. Hoffmann and assistants.

Locality.	Insol.	Cu.	Ni.	Co.	Ni. in Metallic portion.	Authority.
	%	%	%	%	%	
1.—Location W. 7, (W. side Lake Wanapitei)	40	Small quantity	2·00	None.	3·33	R. A. A. Johnston.
2.—Boucher's mine, N.E. side Lake Wanapitei	25	Present.	1·57	"	2·09	" "
3.—Neelon Township, Lot 12, Con. III	....	Small quantity	3·10	Trace.	3·10	"
4.—Boundary line bet. Districts of Algoma & Nipissing, 2 miles N. of Lumsden Tp	....	....	2·70	None.	2·70	F. G. Wait.
5.—Lorne Township, Lot 11, Con. V	Small proportion.	Trifling amount.	1·95	"	....	R. A. A. Johnston.
6.—Lorne Township	33	Small amount.	1·57	"	2·34	" "
7.—Nairn Township Lots 1 & 2, Con. III	Small proportion.	None.	1·95	Trace.	...	" "
8.—Drury Township, Lot 3, Con. III	Trifling amount.	Little.	2·01	"	. . .	" "
9.—Denison Township, Lot 6, Con. II	12·5	None.	1·55	None.	1·77	" "
10.—Levack Township, Lot 7, Con. II	22	"	2·36	Trace.	3·02	" "
11.—Levack Township, Lot 7, Con. II	None.	"	4·13	None.	4·13	" "
12.—Levack Township, Lot 3, Con. IV	18·5	Very small amount.	1·96	Trace.	2·40	" "
13.—Ross mine, W. R., 5, North Nickel Range	16·5	Small amount.	2·75	None.	3·29	" "

Explanations.

Descriptions of specimens on which determinations were conducted.

1. Association of a somewhat coarse granular pyrrhotite, with a small quantity of chalcopyrite, in greenstone.

2. An intimate association of chalcopyrite and pyrrhotite, in a gangue of greenstone.

3. A somewhat coarse granular pyrrhotite, associated, with small quantities of chalcopyrite, from what was then known as the McCormick mine.

4. Pyrrhotite, in association with small quantities of dark-coloured greenstone.

5. Pyrrhotite, with a trifling amount of chalcopyrite, with greenstone.

6. Pyrrhotite, with a little chalcopyrite, with greenstone.

7. Pyrrhotite, with a small proportion of greenstone.

8. Pyrrhotite, with a little chalcopyrite, through which was disseminated a trifling amount of a quartzose gangue.

9. A somewhat coarse granular pyrrhotite, through which was disseminated a small amount of quartz.

10. A somewhat coarse granular pyrrhotite, through which was disseminated a quartzose gangue.

11. A very coarse granular pyrrhotite, free from gangue.

12. A somewhat coarse granular pyrrhotite, with a very small amount of chalcopyrite, in association with greenstone.

13. A coarse granular pyrrhotite, with a small amount of chalcopyrite. The gangue was readily discernible.

These analyses, 1 to 13, were done in the chemical laboratory of the Geological Survey Department, by Messrs R. A. A. Johnston and F. G. Wait, assistants to Dr. G. C. Hoffmann. (Ann. Rep. Geol. Surv. Can. Vol. V. 1890-91, Part R, pp. 41-44 (Nos. 7 to 19).

THE SUDBURY PYRRHOTITE.

Composition of pyrrhotite not constant.

The composition of pyrrhotite, as shown by a large number of analyses, is not constant, and although repeated trials have been made by various chemists and mineralogists, to obtain a formula which would be satisfactory, and representative of this mineral, their attempts so far have been attended with only a fair amount of success.

Formula for pyrrhotite.

It has, therefore, been the custom to express the composition of pyrrhotite, by the formula $Fe_n\ S_{n+1}$ the available analyses, collected by Lindström in 1875, and by Habermehl in 1879, showing a variation of Fe : S = 1 : 1., 1902, corresponding to $Fe_5\ S_6$, to 1 : 1.0610 which agrees with the formula $Fe_{16}\ S_{17}$. Habermehl, from a mean of 14 determinations, ten of which were essentially identical, showed that the Bodenmais pyrrhotite contains 60.57 per cent of iron, thus conforming closely to the formula $Fe_7\ S_8$, the theoretical composition of which would require 60.40 per cent of iron. This material was obtained on portions separated successively from the fine powder, suspended in water by, a strong magnet. Doelter, by artifical means, produced a compound closely resembling, if not identical with the natural pyrrhotite, the analysis of which agreed with the formula $Fe_{11}\ S_{12}$.

Variation in composition of pyrrhotite suggests a possibly mixture.

This variation in composition has suggested the possibility, that pyrrhotite is not really a definite species, in a mineralogical sense but rather, a mixture in varying proportions, of perhaps several closely related compounds. Such a view was regarded as also supported by the wide range in the specific gravity of the mineral, (3.98 to 4.80) as well as, observed differences in the possession of certain physical properties, especially noticeable in regard to its magnetism. Some specimens exhibit this property in such a feeble manner, that only the finer powder is attracted by the magnet, while others are so intensly magnetic, as even to exhibit the phenomenon of polarity.

Discrepancies in results can be explained on other grounds.

Careful consideration of all the facts available, suggest, that much, at least, of the discrepancies in composition, can perhaps be better explained, on other grounds. Thus, although it is known that, a considerable number of these analyses, were conducted on material which had been selected with great care, and using every known precaution to ensure a pure and homogeneous product, by far the larger number of determinations were of impure, often intermixed material. Besides, the methods of analysis were not always above reproach, so that errors constantly occurred, not only in the determination of the sulphur, but also of the iron. In addition, even with the possession of the requisite knowledge of analytical methods, as well as skill in their manipulation it is usually extremely difficult, if not impossible, in all cases, to obtain sufficiently homogeneous material, on which to base a formula, which would be thoroughly reliable and representative. If we regard pyrrhotite as a sulphide, intermediate in chemical composition between the normal sulphide FeS and the disulphide FeS_2 it is possible to obtain every gradation of material showing a range in the iron content, from 63·61 per cent, to 46·60 per cent, while the sulphur to correspond,

Difficulty of obtaining homogeneous material.

Range in composition of sulphides.

would show a gradual increase from 36·39 per cent, to 53·40 per cent. There is, however, a wide gap between $Fe_7 S_8$ with iron 60·40 per cent and sulphur 39·60 per cent, and $Fe S_2$ with iron 46·60 per cent and sulphur 53.40 per cent. Those analyses, however, which have evidently been conducted with the greatest care, show a variation in formula from $Fe_{11} S_{12}$ with iron 61.60 per cent and sulphur 38.40 per cent, to $Fe_7 S_8$ with iron 60.40 per cent and sulphur 39·60 per cent. These determinations are as uniform and accurate as could be expected, from material so manifestly impure as pyrrhotite.

Difficulties of obtaining a reliable analysis of Sudbury pyrrhotite.

A satisfactory and reliable analysis of Sudbury pyrrhotite is, perhaps more than usually difficult to obtain, owing to the very intimate association of various closely related sulphides. In the first place, it was the generally accepted view, that the nickel really replaced isomorphously, an equivalent amount of iron, and was thus an essential constituent of the pyrrhotite, whereas, it is now a well ascertained fact, that by far the greater proportion of the nickel, at least, occurs as a distinct and separable nickel-iron sulphide. Many, however, still cling to the belief, that a small portion of the nickel may exist in a state of chemical combination, but such persons can find little support for this view, in the fact, that, by repeated use of a magnetic separator and with material sufficently comminuted, it is possible to remove almost the last trace of nickel, from a compound, which originally contained from 2 to 5 per cent of this element, while the isolated nickel-iron-sulphide or pentlandite, is usually pure enough for analytical purposes. The process is, however, tedious and repeated trials are necessary, before the pyrrhotite or pentlandite is obtained of the degree of purity desired.

Presence and means of separation of pentlandite

Presence of chalcopyrite.

In addition, other sulphides, mainly chalcopyrite, but sometimes also pyrite are present, the former almost invariably accompanying the pyrrhotite, and all of these are so intermixed with one another, that very fine grinding, and the assistance of magnetism is necessary, before a satisfactory and complete separation can be effected. Such a dissociation, however, may be conducted at the same time as the trials for the elimination of the pentlandite are proceeding, while this latter mineral, which is itself feebly magnetic, can, in turn, be separated from the copper and iron pyrites, which do not possess the property of magnetism, in any sensible degree. The chief difficulty, however, encountered in the purification of the pyrrhotite, arises from the fact that a small quantity of magnetite (Fe_3O_4), often amounting to not less than 1 per cent of the whole, is almost invariably present. C. W. Dickson, after a number of experiments, found, that by treating the sample with dilute (10 per cent) solution of nitric acid, the pyrrhotite

Magnetite which is always present the chief difficulty.

could be largely removed, while the magnetite was but little affected. The separated sulphur was removed by means of bromine and carbon-bisulphide; and after several treatments, the residue of magnetite was obtained pure, and the iron was estimated by titration. The nature of these operations, as he remarks, involves the possibility of some loss, especially as the amount of magnetite is comparatively small, but, on the whole, the method answered very well. The greater number of the analyses indicated that the pyrrhotite could be represented by the formula Fe_8S_9, while two or three others worked out to Fe_7S_8 and Fe_9S_{10}. The first mentioned formula may be regarded as the most probable for the pyrrhotite from the Sudbury District. He likewise mentions the interesting fact, that a trial of a specimen from Rossland, B.C., showed it to be represented by the same formula (Fe_8S_9).

Methods for removal of magnetite.

Formula for Sudbury pyrrhotite.

Formula for Rossland pyrrhotite.

The pyrrhotite is always massive and amorphous, showing all gradations of texture from very finely to very coarsely granular, the coarser varieties possessing well marked cleavages in two directions. As may be seen by a reference to the analyses, there is little or no foundation for the popular belief, that the coarsely crystalline varieties are relatively poorer in nickel, than those which are finer grained. Good crystals are extremely rare, and although occasional fragments are found which are apparently bounded by crystal faces, such planes are really the direct result of cleavage. Perhaps the only authenticated crystal of pyrrhotite, was obtained by Mr. G. R. Mickle, from a man working in the Worthington mine. Mr. Mickle thus describes it: 'The crystal is evidently a hexagonal prism showing strongly marked basal cleavage; two of the sides are intact and portions of two others remain. The dimensions are $1\frac{5}{10}$ inches, or 32mm., by $\frac{1}{2}$ inch, or 13mm.; the weight 27·4 grains; and an analysis of a very small fragment from the crystal gave 2·3 per cent of nickel.'

Physical properties of pyrrhotite.

Description of Mickle's crystal of pyrrhotite.

The colour of the pyrrhotite is a bright steel-gray on fresh fracture, quickly weathering to a deep bronze-yellow, often, however, tarnished or iridescent.

Colour.

CHALCOPYRITE.

The copper contained in the ore is all obtained from chalcopyrite, the common sulphide of copper and iron, ($CuFeS_2$ sulphur 35·0 per cent, copper 34·5 per cent, iron 30·5 per cent=100·0). It is always massive, with the usual deep brass or yellow colour. As usual, this mineral is very subject to tarnish, and beautiful iridescent specimens can be obtained from the ore heaps, or scattered around the works. The composition of the ore varies greatly, as may be seen by a reference to the analyses, and according to the preponderance of either the pyrrhotite or chalcopyrite, the resulting furnace product or

Theoretical composition of chalcopyrite.

Colour.

Mines of Canadian Copper Co. first operated for copper.

matte is relatively richer or poorer in nickel or copper. The mines of the Canadian Copper Company, as the name implies, were first operated for their copper contents and it was not until considerable work had been done that nickel was discovered to be present in the ore. A large shipment of ore had been made to New York, and a chemist there who was making a volumetric determination of the copper contents, by the potassium cyanide process, was struck by the great variation in his results, which led him to make a more minute examination of the ore, when he found that nickel was present. The ore has now become of more value on account of its nickel, than its copper contents, and Dr. Peters himself, greatly doubted, if the mines would pay to work for copper alone.

Discovery of presence of nickel.

Dr. Peter's, doubted if Sudbury mines could be worked profitably for copper alone.

NICKEL AND COBALT IN SUDBURY PYRRHOTITES.

Determinations of nickel, copper, cobalt &c. in Sudbury pyrrhotites.

Locality.	Insol.	Cu.	Ni.	Co.	S.	Iron.	Ni in pure. Pyrrhotite.
	%	%	%	%	%	%	
1. Elsie mine (a)........	2·00	Trace.	2·40	0·06	....	......	2·46
2. " " (b)	3·45	"	2·35	0·05	.....	... ..	2·44
3. Stobie mine (a)......	1·50	"	3·00	0·08	......	......	3·05
4. " " (b)......	4·00	"	2·05	0·05	.....	. .	2·15
5. No. 3 mine (a).... ..	0·40	"	2·35	0·05	....	......	2·40
6. " 3 " (b)..... ...	5·00	"	2·34	0·06	......	.. .	2·48
7. Mount Nickel.........	2·20	"	3·00	0·07	......	.....	3·06
8. Copper Cliff No. 4 mine (a)	1·10	"	3·24	0·06	......	....	3·30
9. Copper Cliff No. 2 mine (b)	5·00	"	3·70	0·08	......	.....	4·00
10. Copper Cliff No. 5 mine (c)........... ...	0·50	"	3·47	0·08	......	.....	3·50
11. Creighton mine (a)...	3·25	"	3·84	0·10	... ..	......	4·00
12. " " (b)...	0·50	"	2·26	0·06	......	......	2·32
13. Gertrude mine (a)....	5·00	"	3·83	0·11	......	......	4·05
14. " " (b)....	6·00	"	3·61	0·09	......	......	4·00
15. Victoria mine (a).....	0·50	"	3·36	0·07	......	.. ...	3·40
16. " " (b)	0·40	"	3·14	0·08	.....	......	3·20
16*a*. " " (b)	3·00	4·50	3·50	......	32·00	55·00	....
17. Levack Township ...	3·20	Trace.	2·80	......	......	.....	2·88
18. Wisner " ...	4·10	"	2·22	.....	.. .	.. ...	2·32
19. Creighton mine (a)...	2·28	0·72	5·31	......	34·28	.....	....
20. " " (b)...	2·49	1·20	4·87	.....	34·62	......	....
21. Copper Cliff (7th level) (a)...................	......	0·00	11·00	......	38·01	50·40	11·00
22. Copper Cliff (7th level) (b).........	......	0·00	4·62	......	38·58	55·70	4·62
23. Stobie mine (a).	......	0·00	2·75	......	35·35	58·00	2·75
24. " " (b)......	......	0·00	2·15	......	36·10	57·00	2·15
25. Evans mine (a)......	... ..	Trace.	9·02	.....	39·28	51·50	9·02
26. " " (b)... .	... ..	0·00	3·82	......	40·18	56·00	3·82
27. Copper Cliff mine....	7·75	Trace.	3·40	0·175	......	......	Co=0·2, Ni 3·98
28. Cryderman mine.....	2·96	"	4·46	0·174	......	......	Co=0·18, Ni 4·60
29. Cochrane mine... ..	11·10	0·10	3·52	0·146	......	......	Co=0·16, Ni 3·96
30. Little Stobie mine. ..	2·70	Trace.	4·06	0·165	......	......	Co=0·17, Ni 4·17

EXPLANATIONS.

Methods employed for obtaining samples.

Analyses 1-18 inclusive, with the exception of 16a., were made by Mr. C. W. Dickson, (Trans. Amer. Inst. Min., Eng., Albany meeting, Feb. 1903) in duplicate or triplicate, to insure the greatest possible accuracy. These were made to ascertain as accurately as possible, the average nickel and cobalt contents, of the general run of the pyrrhotite, from the whole region. The pyrrhotite was coarsely crushed, and the mineral picked out as pure as possible, under a lens, when necessary. From the massive varieties, good samples were easily obtained, but, in other cases, the pyrrhotite was so intimately mixed with chalcopyrite and rock, that it was very difficult to obtain satisfactory samples, some rock always adhering to the sulphide. The results obtained, show, that the percentage is fairly constant over a wide area. The pyrrhotite includes both fine and coarse-grained. In the case of the coarse grained varieties, where the nickel mineral pentlandite can often be recognized, this was carefully rejected, as far as possible. But the difficulty of separation accounts for the fact, that some of these varieties show less nickel than the finer grained ones, although the former are usually considerably richer. Had the coarse-grained samples been treated in their original condition, the results would have been more uniform. These analyses, therefore, represent the nickel which is most intimately associated with the pyrrhotite, and does not appear as particles of pentlandite.

Explanation of variation in results.

Description of specimens analyzed.

1. Coarse pyrrhotite, with a small amount of chalcopyrite and rock; 2. Compact fine-grained pyrrhotite, with a small amount of rock; 3. Massive, fine-grained pyrrhotite; 4. Pyrrhotite and chalcopyrite, in diorite; 5. Pure, coarse pyrrhotite; 6. Fine-grained pyrrhotite; 7. Massive pyrrhotite; 8. Coarse pyrrhotite; 9. Massive, fine-grained pyrrhotite; 10. Massive, fine-grained pyrrhotite; 11. Massive, fine-grained pyrrhotite; 12. Coarse pyrrhotite; 13. Massive pyrrhotite; 14. Massive pyrrhotite; 15. Massive, fine-grained pyrrhotite; 16. Coarser than No. 15, but with more chalcopyrite; 16a. Analysis of ore by Mond Nickel Company; 17. Massive pyrrhotite (Tough and Stobie's property); 18. Coarse, massive pyrrhotite, from the Northern Nickel Range; 19 and 20 are analyses by Mr. Donald Locke. Analyses 21 to 26 inclusive, are of ore selected for purposes of magnetic concentration, by Mr. David H. Browne. Analyses 27 to 30 inclusive are by Mr. M. F. Connor of this Department, and were of hand-picked ore, as free as possible from chalcopyrite and gangue. All of the specimens were of pyrrhotite, of medium-grain, with the exception of that from the Little Stobie mine, which was a very coarse cleavable variety.

MODE OF OCCURRENCE OF THE SUDBURY NICKEL DEPOSITS.

Deposits are not veins.

Most geologists, at least, who have examined these deposits in detail, are agreed, that they are not true fissure veins, and although, at times certain sloping surfaces are obtained, which seem to have a uniform inclination and limit the distribution of ore in their direction, yet, it seems certain, that there are no regular walls, in the miner's sense of the term, and at both sides of the deposit, the enclosing rock is impregnated, more of less, with pyritous matter. Although mining is thus rendered somewhat difficult and uncertain, on account of the absence of the walls, and irregularity in the distribution of the ore, so that there is very little means of knowing in what direction to drive the levels, this uncertainty is usually more than compensated by the extent and massiveness of the deposits, when found.

No regular walls.

Irregularity of distribution of ore.

Shape of ore bodies.

The ore bodies are of irregular, oval or pod-shaped outline, and all agree in having their longer axes to correspond very closely with the direction of the foliation of the enclosing rocks. The shapes and dimensions of the ore bodies of the International Nickel Company's mines at Copper Cliff, are accurately shown on the accompanying large scale maps. There are three main types of these ore deposits in the Sudbury Mining District.

Three main types of occurrence.

Marginal deposits.

1. Those which occur at the southern border of the immense body of hypersthene-gabbro, or norite, which reaches without interruption, from Drury to Garson townships. Under this division, are included the Gertrude, Creighton, North Star, Tam O'Shanter, Lady Violet, Elsie, Murray, Cameron, Little Stobie, Mount Nickel, Blezard, Beatrice, Kirk. wood and Cryderman mines.

Offset deposits.

2. Those which are developed in connection with offsets or dyke-like forms of the norite, extending southward from the main mass, and which are intruded into the older rocks, almost at right angles to the planes of foliation and bedding. This would embrace such mines as the Victoria, Clarabelle (No. 6), No. 4, Lady Macdonald (No. 5) and No. 2, and the extensions of No. 2 mine.

Deposit occurring with small isolated masses of norite.

3. Those which are associated with smaller, and at present, completely isolated bodies of norite. These separate masses of the nickel bearing eruptive, are so closely identical, in mineralogical composition, structure and behaviour to the parent eruptive, that they are probably connected with it, in some way, at a distance below the surface.

The original Copper Cliff, No. 1 and its extensions, Evans, Frood (No. 3) and Stobie mines are all examples of this last mentioned class.

The first mentioned division of deposits, are all situated at the immediate contact between this huge mass and the older rocks, into which it is intruded. The intrusive nature of this contact is well shown, the impregnation of the older green schists consisting, for the most part, of small, dyke-like forms, or veins of sulphide material, injected along the planes of schistosity, while, on the other side, the line of separation between the ore-body and the norite is even more uncertain, the sulphide material gradually fading out, until it is only represented by occasional disseminations. To the northwest, this basic rock shows a gradual differentiation or passage into the peculiar and characteristic type of gneissic granite, usually referred to as 'micropegmatite'. On the Levack or Middle Range (Windy lake eruptive), this condition of affairs, is reversed, and we find the deposits at the northwestern margin of the norite, while its differentiate, the micropegmatite lies to the southeast. This same condition of affairs obtains on the Northern Nickel Range where the norite comes in contact with the older granites and green schists on the north side, while the micropegmatite underlies the area to the south.

Description of marginal type of deposit.

Differentiation of norite into micropegmatite.

The Worthington and the Vermilion mines are the only deposits which have been developed, having no visible connection with the main mass of norite already noticed. As has been shown on a previous page, the Worthington mine occurs on a narrow neck of actinolite diorite, which is, without doubt, the altered representative of the older norite. To the southwest and east, this norite is directly connected with a much larger mass of basic eruptive material. As far as can be learned, no large deposit of ore was encountered at the Vermilion mine, and the small amount of norite found, resembles very closely, the decomposed variety of the older type of this rock.

Worthington and Vermilion mines not connected with main body of norite.

Rounded hills of gossan, indicating the presence of the more or less pure and unaltered ore beneath, extend with almost unbroken continuity, for miles along the line of junction, while by far the larger portions of the offsets and isolated masses, with which the ore-bodies are associated, are also of a prevailing brownish colour, from the decomposition of the abundantly disseminated sulphides. This gossan has resulted, as usual, from the alteration of the pyrrhotite and chalcopyrite, and the formation of hydrous oxide of iron, which gives a prevailing brownish colour to the upper portions of the deposits. This covering of iron oxide is sometimes as much as six feet in depth, although usually it is only two or three feet, gradually merging into the unaltered ore beneath. The depth to which this gossan extends depends largely, of course, on the length of time the deposits have been uncovered, and thus exposed to processes of weathering. Some, from which the green forest and overlying soil have but lately been removed,

Significance of occurrence of gossan.

Explanation of formation of gossan.

Depth of gossan.

show little or no iron oxide, while others like the Murray mine which have been exposed to the action of the weather for years, exhibit an extensive covering of this characteristic decomposition product. From the Elsie mine, in a northeasterly direction, past the Murray mine as far as the boundary between McKim and Blezard townships, a considerable belt of rock occurs at the immediate margin of the norite, so heavily charged with sulphides, that its weathered outcrop at the surface is covered with this gossan. At the old Copper Cliff mine, as well as at the Creighton mine, this overlying gossan is very wide spread and deeply impressive.

Gossan from Elsie mine northeast.

Gossan at Copper Cliff and Creighton mines.

Brecciation of ore body.

In most cases, these ore-bodies show a brecciated character, large angular or partially rounded blocks, of almost barren rock being mingled with the ore. Some of these horses, as they have been called, are made up of the material derived from the wall rock, against which the pyritous matter cooled. Their presence, in this connection, is no doubt due to the shattering of the invaded formation, at their contact with the plutonic magma. In fact, they form an illustration, on a small scale, of the phenomenon of 'overhead stoping', so fully described and explained by Dr. R. A. Daly.(1) In other instances, however, this comparatively barren material is of norite but such inclusions are seldom sharply defined from the sulphide, exposures showing a gradual transition from one to the other, while the blocks themselves are generally more or less plentifully impregnated with the prevailing sulphide.

Explanation of brecciated structure.

No great depth reached by marginal deposit workings.

No great depth has yet been reached by the workings of any of the mines of the marginal type of deposits. The deepest of the shafts is at the Blezard mine, which has only been sunk a distance of 172 feet while those of the Murray and Gertrude are 160 and 120 feet deep' respectively. On the other hand, the diamond drilling undertaken at the Creighton, is stated to have proved the existence of this phenomenally large body of nickel ore, to a depth of at least 400 feet. This wonderful deposit of pyrrhotite has been worked, mainly, as a large open pit, measuring 150 by 200 feet, and extending to a depth of 62 feet. All of these deposits dip to the north and northwest at an angle varying from 30° to 70°.

Open pit at Creighton mine.

Depth of offset deposits.

Of the mines belonging to the second group of those developed along the offsets, the two most important are the Victoria mine and the No. 2 mine, of the International Nickel Co., at Copper Cliff. The Victoria mine, of the Mond Nickel Company, with seven levels and extensive slopes, has reached a depth of 557 feet. The No. 2 mine has afforded a large amount of ore, being worked, for the most part as a large open pit, measuring about 250 feet in length, by 100 to 150 feet in width, and with a depth of 217 feet.

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(1) Amer. Jour. Sc. Vol. XVI., 1903, p. 108.

Description of Copper Cliff ore body.

The original and famous Copper Cliff mine has often been, referred to as a chimney of ore, averaging in width from 50 to 100 feet in the cross section, through the shaft, while at right angles to this direction, it varies from 30 to 210 feet. The first or old shaft, now in large part abandoned, except for pumping purposes was sunk to a depth of over 500 feet, on an incline of 40°, while shaft No. 2, or the new shaft to take its place, starts from the third level, at a distance of 150 feet from the surface, and continues at an angle of 77°30′, or approximately parallel to the ore body, to the 14th level (depth 1,058 feet.)

Depth reached at Copper Cliff mine.

Depth of Stobie mine.

The ore body of the Stobie mine, developed in connection with a small isolated mass of norite, has an inclination of 65°, and, although, the workings have only reached a vertical depth of 250 feet, it has yielded a larger amount of ore than any other mine in the district (415,000 tons).

ORIGIN OF THE ORE DEPOSITS.

Origin a matter of much speculation and discussion.

The question, as to how these abnormally large masses of sulphide material, acquired their present position and dimensions, has furnished a fruitful topic for speculation and discussion, ever since their first discovery. Fortunately, however, only two theories, with some minor modifications, have been advanced, in explanation of the manner of their formation, and which may be summarized as follows :—

Two principal theories.

Igneous origin.

1. That the sulphides are directly of igneous origin, the products of the differentiation of a gabbro or norite magma, being segregated along its margin in obedience to Soret's principle, the order of formation of the minerals being in accordance with Fournet's series.

Secondary or aqueous origin.

2. That those ore bodies are altogether of secondary and aqueous origin, occurring as replacements along crushed and faulted zones.

Extreme advocates of both theories ignore certain evidence.

The extreme advocates of either theory, seek to ignore the share of the other in forming these deposits, as they exist at present. Thus, those who originally held that these ores were the immediate product of magmatic segregation, failed to mention, or at least emphasize the possibility, that those deposits, were, in any way, influenced by the presence of these heated solutions, which to a certain extent accompany, and in all cases immediately follow all plutonic action. On the other hand, those, who consider these deposits as of secondary origin, in seeking to explain the source of the metals, although they acknowledge as a fact, 'that the universal association of these ores with essentially similar rocks is also striking' and again 'that the norite, (or gabbro) has an intimate connection with the development of the ores cannot be doubted, but in just what way they are related is not clear', still at the same time, they nullify any effect which might be produced by such information. by a statement, to the effect, that 'an appeal must be made to a more distant source of the metals, probably minutely disseminated in the rocks through which the depositing solution passed.' (¹)

First statement in regard to origin of these sulphide deposits.

The writer, who was one of the first to affirm a direct igneous origin for these Sudbury ores, giving independent expression to precisely similar views, which about the same time were stated, in much more detail, by Professor J. H. L. Vogt, of Christiania, Norway, realizes the fact that, in the first endeavour to fix definitely, the responsibility for these unusual occurrences, too much emphasis was perhaps given to the idea of magmatic differentiation, as in itself, giving an adequate explanation of all the phenomena witnessed. This can only be excused on the ground that, this doctrine as applied to ore deposits, was an entire innovation, and its strongest affirmation, was at first, very necessary in order to effect its recognition as a previously ignored, though important factor, in the development of ore deposits. More recent and detailed examination of the various ore bodies, has shown that while the first hypothesis of a segregation of these sulphides, directly from the magma, is in the main, the true explanation of their present position, other agencies, which are usually grouped together under the name of secondary action, have contributed rather largely, to bring about their unusual dimensions.

Magmatic differentiation although in the main the true explanation is not the only contributing cause to the formation of these ore deposits.

Prof. Kemp regards igneous rocks as original source of ore.

As Professor Kemp remarks, (²) 'increasing experience leads us to look with especial favour on the igneous rocks as the original source of the ore, whose widely disseminated, although, when considered in comparison with their mass, whose small percentages of all the metals, except the invariably abundant iron, suggest to us original stores for leaching. We are also attracted to them, as a source, because without doubt, all other rocks must be ascribed to them in the last analysis; because they are so often in close association with ores as mined, and because, above all, they are the natural stimulators of those heated solutions, to which we can, with most reason, attribute the results.'

Present opinion in regard to fused magmas.

At the present day, fused magmas are regarded as more or less complex solutions, which, by reason of their high temperatures, obey the same laws in the order and method of their solidification, as those which govern the crystallization from ordinary solutions, of a simi-

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(1) Trans. Amer. Inst. Min. Eng., Albany Meeting, Feb., 1903.
(2) Min. Industry, Vol. IV, 1895, pp. 756-757.

larly heterogeneous composition. A study of thin sections of igneous rocks, under the microscope, reveals the fact, that a certain definite order in the generation of the component minerals is always observed, which is closely followed, in the cooling of any body of magma. Thus, in a gabbro or norite magma, the oxides of iron and titanium, the sulphides of iron, nickel and copper, zircon and apatite are the first to crystallize. These are followed by the ferromagnesian silicates, olivine, hypersthene, biotite and diallage. The plagioclase may antedate, accompany or immediately follow the crystallization of one, or more of the coloured constituents, depending on its basicity, while quartz is invariably the last to form, filling up all the irregular interspaces remaining. One of the main laws, governing the crystallization from a solution, or an igneous magma, is known as Soret's principle, according to which, the dissolved matter is concentrated in the coolest part of the solution. Gravity, temperature and pressure are also important factors, but these have not yet been deeply investigated.

Order of generation of component minerals as determined by microscope.

Laws governing crystallization of magmas.

Perhaps one of the most significant developments of modern petrographic geology, has been the recognition of the fact, that an originally homogeneous molten mass, tends to so separate or split itself, upon cooling, as to ultimately produce rocks of varying composition. This fact, bearing so intimately on the genesis of igneous rocks, has caused the formulation of the hypothesis known as magmatic differentiation. The hypothesis may be briefly described as the division or differentiation of a more or less viscous magma, or fused mass of rock, into chemically and mineralogically diverse parts, which on cooling, yield correspondingly different types of rocks. It would be manifestly unwise in this connection, to enter into any detailed explanation of this very generally accepted hypothesis, as the conditions attending the consolidation of a large body of magma, are now believed to be much more complex than at first supposed. Moreover, our knowledge regarding these conditions, and the several processes which are no doubt involved, is so vague and incomplete, that no full or satisfactory explanation can yet be offered of this phenomenon. All geologists of repute are, however, agreed on the main fact, that magmatic differentiation furnishes the only reasonable explanation of most of the observations made in connection with any extended exposure of igneous rocks.

Definition of magmatic differentiation.

Unnecessary to discuss hypothesis at length.

Our knowledge still incomplete.

All geologists agreed on general hypothesis.

Applying these principles to the geological relations of the Sudbury gabbro or norite, and the associated sulphide deposits, the subjoined facts seem to furnish unanswerable proof that the hypothesis of a segregation of these ore bodies, directly from the magma, is, in the main, the true explanation of their position.

Sudbury ore bodies mainly segregations from magma.

Deposits all occur at the margin of the norite.

1. The deposits, without exception, all occur at the margin of the gabbro or norite, the rock itself in immediate association with the ore being finer in texture and relatively much more basic in composition, than portions further removed from the contact. There is a very gradual increase in the basicity of the gabbro, outward from the micropegmatite, although a rather abrupt transition takes place in the immediate neighborhood of the contact. The sulphides are also finer grained near the contact, while further away, they becomecoarser grained. (1)

Sulphides more sharply defined against the walls of the intrusion.

2. The sulphides are always much more sharply defined against the walls of the intrusion, than on the inner side towards the main mass of the gabbro, the transition in this direction showing a more gradual decrease in the amount of ore in the rock, as the contacts are left This phenomenon, as has been mentioned, is explained by the fact, that the sulphides in obedience to Soret's principle, become concentrated towards the cooling surface of the mass.

Deposits always found in intimate connection with norite.

3. These deposits are always found in such intimate association with the norite or hypersthene-gabbro, that we are forced to the conclusion, that the ore bodies stand in some genetic relation to this plutonic igneous rock. This is not only true in regard to the Sudbury District, but is also the invariable association of precisely similar deposits, found in Norway, Sweden, Lombardy and Pennsylvania. The importance of geological studies, in connection with ore deposits, is emphasized by the fact, mentioned by Adams, (2) that although, in these several widely separated countries, the pyrrhotite deposits, associated in the manner described, with the gabbros, are so rich in nickel, the celebrated Fahlbands of Norway, which are bedded or apparently bedded deposits, consisting of heavy impregnations of pyrrhotite, pyrite, chalcopyrite, etc., but occurring in gneisses and schists of various kinds, contain hardly any nickel, hundreds of analyses showing the nickel and cobalt contents, to range from 0·1 to 0·5 per cent, and what is still more remarkable, the same is true of the similar Fahlbands, associated with our Laurentian in Canada, so far as these have been examined. In these, the pyrrhotite and pyrite is present in large amount, and is often associated with copper pyrites, but only a very small quantity of nickel and cobalt, ranging from faint traces to 0·16 per cent, occurs in the pure sulphide material. In addition, pyrrhotite, chalcopyrite and pyrite occur sometimes, in promising quantities, in the older green schists and tuffs of the Sudbury District, but even the richest of these deposits, were shown by analyses, to contain a much smaller amount of nickel, ranging from 0·45 to 0·96 per cent, in the pure pyrrhotite.

Fahlbands quite distinct in origin and nickel contents.

Sulphides in older green schists and tuffs contain much smaller amounts of nickel.

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(1) Quart. Jour. Geol. Soc. Lon., Vol. LIII, 1897, p. 52.

(2) 'On the Igneous Origin of Certain Ore Deposits,' Montreal, 1894, p. 17; also, Ann. Rep. Geol. Surv. Can., Vol. VI, 1892-93, part J.

4. Pyrrhotite, chalcopyrite and pyrites are all ordinary constituent minerals of the normal norite, and are, at times, comparatively abundant even in exposures situated some distance from the contact. We may readily obtain, at any of the mines, specimens which exhibit every gradation in the amount of these sulphides present in the rock, from the ordinary type of norite, with occasional disseminated grains of the pyritous matter, to what has been referred to by Vogt, as 'pyrrhotite-gabbro or norite' with from 5 per cent to 50 per cent, or even 80 per cent of pyrrhotite, while portions of some of the deposits, are made of practically pure pyrrhotite and chalcopyrite, with little or no gangue matter.

Sulphides are ordinary primary constituents of norite.

Occurrence of 'pyrrhotite-norite.'

5. The sulphides are, undoubtedly, of primary origin, and are among the earliest of the minerals to crystallize out from the original magma, sometimes even antedating the iron ore, in which they are occasionally completely enclosed. They occur in very much the same way as the iron ore, embedded in, or in the immediate vicinity of the various coloured constituents. In fact, individual grains can only be distinguished from one another by their colour in reflected light. This intimate association between the iron ore, not only occurs in the normal norite, but even the ore bodies themselves, especially those of the North Range, which almost invariably contain titaniferous magnetite often in appreciable quantities. Occasionally, considerable masses of magnetite, sometimes several tons in weight, are encountered in the working of the mines, which are completely enclosed in the sulphide material, while this iron ore itself contains disseminated grains of the pyrites, in addition to certain decomposed silicates belonging to the norite. The relations which obtain between the sulphides and the norite, are closely analogous to deposits of magnetite, occurring in connection with certain basic igneous rocks in central Ontario. In these deposits, the magnetite is the abundant ore, while the sulphides are usually present in subordinate amount. The enclosing rock, usually shows much more alteration, than in the case of the norite associated with the Sudbury sulphide deposits.

Sulphides undoubtedly of primary origin.

Similarity of mode of occurrence of sulphides and iron ore.

Occurrence of large masses of magnetite.

Resemblance to iron ore deposits of central Ontario.

6. The transitional type between the normal norite and the richer forms of the pyrrhotite-norite, furnishes unmistakeable evidence, that in these cases, at least, the sulphides were formed during the cooling and crystallization of the norite magma, and that they were very little affected by any secondary action. The only effects of pneumatolytic or vein action noticed, consisted in the more or less complete alteration of the pyroxene minerals, while much of the plagioclase is surprisingly fresh and glassy. Although, most of the rock matter associated with the ore bodies is more or less decomposed, the alteration is not of the

Evidence that sulphides were formed during cooling of norite magma.

Alteration not of extreme type.

Occurrence of fresh representatives with high content of sulphides.

Least altered varieties often found in vicinity of mines.

extreme type, which would be expected if the whole of the deposits resulted from secondary action. The writer's collection of rocks contains specimens of the pyrrhotite-norite, sometimes containing as high as 10 per cent of the sulphides, from most of the principal mines, which are so free from alteration, as to permit of the precise identification of both the orthorhombic and monoclinic pyroxenes. The rocks in the immediate vicinity of the ore bodies are not, therefore, as generally described, so made up of secondary minerals, as to thoroughly obscure their original composition and structure, but, on the contrary, the least altered representatives of the norite, may readily be obtained at, or in the immediate vicinity of any of the mines.

Fournet's series.

Explanation of order of formation of sulphides.

7. Fournet has shown, that sulphur, when dissolved in a molten magma of silicates, shows affinity for the metals in the following order: copper, nickel, cobalt, iron, tin, zinc, lead, silver, antimony and arsenic. The small percentages of copper, nickel and cobalt, present in the original magma, unite with the sulphur, and thus become concentrated in any sulphide of iron which separates, while any tin, zinc, lead, silver, antimony or arsenic, present in the magma, is not so concentrated.

Percentages of nickel, cobalt and copper in nickeliferous rocks of Norway.

8. Vogt (¹) mentions, that if we were to distribute the whole metallic contents of the ore deposits, through their respective mother rocks, in Norway, these would have the following percentages: nickel, 0·03 per cent to 0·12 per cent; cobalt 0·005 per cent to 0·017 per cent; and copper 0·015 per cent to 0·05 per cent. No attempt has been made to calculate these percentages, with regard to the Sudbury District, but the above results are just about what would be expected from our knowledge of the nickel contents, generally, in the basic silicates of rocks.

Browne has shown that differentiation Takes place in pot of matte.

9. One difficulty which has often been urged against the direct deveopment of these deposits from a state of igneous fusion is, that it would be impossible to obtain such large and comparatively pure concentrations of the sulphides. Mr. David Browne (²) has shown by numerous analyses and diagrams, that in a pot of matte the nickel tends to concentrate towards the centre, while the copper is much richer at the [illegible]. This is exactly the experience in mining. 'These observations', Prof. Kemp remarks, 'are extremely important, showing as they do the migration of metallic matter even in so viscous and quickly chilling a mass as a pot of matte.'

Proofs of solution of sulphides in eruptive magmas.

10. Vogt believes that eruptive magmas may keep dissolved even very considerable quantities of sulphides, supporting his belief by the

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(1) Min. Industry, Vol. IV, 1895, p. 748.

(2) School of Mines Quarterly, Columbia College, July 1895, p. 297; also Min. Industry Vol. IV., 1895, p. 762.

fact, that basic blast furnace slags usually hold from 3 to 5 per cent of sulphides, especially CaS and MnS; likewise, the basic ferriferous slags from copper, nickel and lead smelting may contain from 4 to 6 per cent FeS and the basic zinc slags even 6 to 8 per cent ZnS. Sandberger separated the dark silicates of many rocks and proved them to contain copper, nickel, cobalt, lead, tin, antimony, arsenic, bismuth and silver.

11. Galena, zinc blende, and compounds of arsenic and bismuth are either completely wanting or present in very insignificant amount.

Compounds of lead arsenic and bismuth rare.

12. The remarkable scarcity of boracic and fluoric minerals and other secondary products which usually attend any pronounced or long continued vein action.

Secondary minerals scarce.

13. Secondary quartz, calcite and dolomite are occasionally present, in appreciable amounts, but the prevailing scarcity of these minerals, at most of the deposits, has always been a subject of remark, and the first mentioned mineral has often been brought from considerable distances, not only to line the converters, but also to add to the furnace charges, even at such mines as the Victoria, where secondary quartz is relatively perhaps more abundant than at any other deposit in the district.

Quartz, calcite and dolomite by no means abundant.

14. Platinum, usually, at least, in the form of sperrylite, is found in small quantities, at all of the deposits. Such an occurrence seems to be closely related to the native platinum and osmiridium metals, in the altered basic olivine rocks of the Urals and elsewhere.

Occurrence of platinum also points to igneous origin.

15. The deposits are singularly uniform in chemical and mineralogical composition, and their monotonous character, in this respect, has been frequently commented upon. A careful study of the analyses will serve to further emphasize this fact. This peculiarity holds good, not only with regard to the Sudbury deposits, but applies with equal force to those of Norway and elsewhere, wherever full details of composition are available. The characteristic minerals of this 'world group,' as it has been called, is everywhere the same. Pyrrhotite, with generally from 2 to 4 per cent of nickel and cobalt, although occasionally reaching as high as 10 to 11 per cent of nickel, pyrite (in Norway relatively rich in cobalt), pentlandite, together with some chalcopyrite, and some of titaniferous magnetite are always present in the norite or gabbro. The nickel minerals polydymite, millerite, etc., are also often present, but only in very subordinate amounts.

Uniformity in composition of deposits.

Occurrence of 'world group' of sulphide minerals.

16. Brecciation, which is so frequently characteristic of these deposits, is an almost constant feature of eruptive contacts, resulting from the detaching of material from the containing walls. The frequent angular

Brecciation, characteristic feature of eruptive contacts.

character of these blocks is due to their imperfect assimilation by the fused basic magma, in which they have been floated off.

Many of these views previously stated.

These are some of the main points, which may be urged in support of the hypothesis of magmatic differentiation, as explanatory of the origin of these Sudbury ore deposits. Many of them are not new, and have been stated in more detail by Vogt, Adams, Kemp and others. They are introduced, in the present instance, as the trend of some of the more recent examinations seeks to ignore the full significance of the intimate genetic relationship which exists between the norite and the ore bodies, affirming that secondary causes or replacement are alone and directly responsible for the present position and dimensions of these deposits.

Trend of some modern work seeks to ignore full significance of association.

Classification of eruptive ore deposits by Vogt.

Vogt, (1) in his classification of eruptive ore deposits, divides them into two chief groups. 1. Deposits formed by 'magmatic differentiation'; that is by the concentration of some metallic parts within the still fluid eruptive magma. 2. Deposits formed by processes subsequent to the eruption or 'after actions' as they have been sometimes called ;—that is by pneumatolysis, fumarole action, hydrothermal agents and the like, directly consequent on the eruption.

Transition between Vogt's subdivisions.

The trend of modern geological investigation, seems to emphasize, more and more, the fact that no really sharp division exists, as indicated by Vogt's sub-divisions but that processes, which at the two extremes are manifestly very widely divergent in their effects, are so intimately associated, in time and manner of operation in nature, that the resultant product cannot, with any degree of propriety, be attributed wholly to either group of processes.

Researches of Fouqué and Michel-Lévy.

Thus, although the researches of M. Fouqué and Michel-Lèvy, have clearly shown that diabase and kindred basic eruptive rocks may be artificially reproduced from a simple state of dry fusion, it is equally certain, that no extended intrusive process, produced by natural causes, is ever unaccompanied by a greater or less abundance of superheated waters and vapours, as an integral portion of the fused mass. As a general rule, these heated solutions are relatively much more abundant in the case of the acidic magmas than those of more basic composition. It is thus obvious, that all igneous action is both accompanied and, in a more extended manner, immediately followed by more or less pronounced vein or pneumatolytic action (secondary causes), and certain rocks and mineral occurrences may be representative of the various

Fused magmas always accompanied and immediately followed by superheated waters and vapours.

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(1) Zeit für Prak. Geol., 1893, pp. 4-11 ; 125-143 ; 257-284 ; also 1895, pp. 145-156 ; 367-370 ; 444-459 ; 465-484.

transitions between what has been termed aqueo-igneous fusion and igneo-aqueous solution. The abnormally large amount of original or primary quartz, so uniformly distributed throughout the Sudbury norite or gabbro, has been repeatedly mentioned and commented upon by the various geologists, who have examined these rocks in detail under the microscope. It thus naturally follows, that the agencies grouped together under the name of secondary action, would be much more actively effective in connection with the ore bodies and other segregations resulting from the eruption of such a rock, than with the ordinarily less quartzose or basic varieties of such rocks. The manner of formation of these ore bodies, as thus indicated, is much more complex than was at first supposed. There can be no doubt, however, that much of the sulphide material was introduced simultaneously, as an integral portion of the same magma, along with the other minerals of which the norite or hypersthene-gabbro is composed. There can, moreover, be little doubt of the abundant presence of heated solutions and vapours, which were capable of dissolving out, and under certain conditions, of redepositing these sulphides. Such agencies certainly began their work before the whole magma had cooled, bearing their heavy burdens of sulphide material, most of which was obtained from the magma in the immediate vicinity, to occupy the various cavities and fissures as fast as these were formed. The whole of this action was practically completed before the intrusion of the later dykes of the olivine-diabase which are now regarded by the writer, as the end product of the vulcanism to which the norite masses owe their intrusion. In certain of the deposits, the various hydrochemical agencies accompanying dynamic action have been more active than in others, as at the Victoria mine, and some of the Copper Cliff mines, but in others, as for instance, the Creighton mine, magmatic differentiation has been the main and almost sole principle, determining and favouring the development of this the largest and richest sulphide nickel mine in the world. The enunciation, in the first place, of the simple doctrine of the direct igneous origin of these ore bodies and their intimate relationship in this respect, to certain bands of norite or diorite, served an excellent practical purpose, in directing and controlling all the earlier prospecting work.

Significance of occurrence of abundant primary quartz.

Manner of formation of ore bodies much more complex than at first supposed.

Concentration of ore completed before intrusion of diabase dykes.

Magmatic differentiation at Creighton mine.

After all, however, the origin of these ore deposits is largely a matter of theory and opinion, and strong arguments may be adduced in support either of the view, that they are the direct result of magmatic segregation, or that the sulphides were brought up in a state of solution from considerable depths, to replace certain portions of the rock, or to fill up spaces caused by structural weakness. The real practical side

Origin of ore bodies a matter of theory and opinion.

Outlining of norite of great practical importance.

of the geological investigation, consisted in the outlining of the immense masses of intrusive norite or gabbro, with which the nickel and copper deposits of the region are alone associated.

MAGNETIC SEPARATION OF NICKELIFEROUS PYRRHOTITE.

Early separation of pyrrhotite by magnetism.

The application of magnetism, either to free the pyrrhotite from impurities, with which it is so frequently intermixed, in order to obtain a homogeneous and pure product, for analytical purposes, as well as to effect a separation of the nickel present in the pyrrhotite ores, is by no means a novel idea, and many experiments have already been undertaken with this end in view. In 1879, Habermehl succeeded in dividing the Bodenmais pyrrhotite, into magnetic and non-magnetic portions respectively, using fine powder, suspended in water, by a strong magnet. The magnetic portion thus separated, by successive trials, furnished a product which was so homogeneous and uniform, that ten out of fourteen of the determinations for iron content were essentially identical.

Magnetic trials by McTighe.

In 1890, T. J. McTighe (¹) applied magnetic separation in the treatment of the nickeliferous pyrrhotite of Canada.

Edison's description of constitution of pyrrhotite.

In July, 1892, Mr. Thomas A. Edison, in applying for a United States patent, embodying the same principle, gave the following explanation in support of his claim. 'I have discovered that when magnetic pyrites, called "pyrrhotite," is nickeliferous, as it usually is, to a more or less extent, the nickel is distributed generally throughout the whole body of the pyrrhotite, but certain crystals are pure pyrrhotite or magnetic pyrites, while other crystals have some of the iron replaced by nickel and sometimes by cobalt, and that the crystals, containing the nickel or cobalt, are considerably less magnetic than the pure pyrrhotite.'

Magnetic experiments by Dr. Emmens.

In the same year, (1892), Dr. S. H. Emmens (²) carried on certain magnetic experiments on material obtained from the Gap mine, Penna, and Sudbury, Ont. These were undertaken, not only for the purpose of testing the accuracy, or otherwise, of the theory of the replacement of a portion of the iron by nickel in pyrrhotite, but also to arrive at a more accurate expression of the composition of pyrrhotite, by means of a formula. The practical side of the question was not ignored, and a

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(1) Ann. Rep. Bur. of Mines, Ont., 1892, p. 164; also Jour. Am. Chem. Soc., Vol. XIV, No. 10.

(2) Ann. Rep. Bur. of Mines, Ont., 1892, pp. 163-166; also Jour. Am. Chem. Soc., Vol. XIV, No. 10.

statement of the relative abundance of the separated portions is given, with their respective contents of nickel.

Methods of separation employed by Dr. Emmens.

Dr. Emmens mentions that he obtained his material from a mine near Sudbury, but does not specify the precise locality. He also neglects to give necessary details of the composition of the ore selected, except that the gangue formed 10·7 per cent of the whole. In regard to the preparation of the material for purposes of separation, he states that the sample was very finely powdered, and carefully separated by means of a magnet into three grades, namely, 'magnetic', 'feebly magnetic' and 'non-magnetic'. The magnetic and non-magnetic grades were then submitted to analysis, resulting as follows, after deduction of gangue.

Composition of separated products.

Magnetic.	Analysis.	Feebly Magnetic.	Non-Magnetic.	Analysis.	Division of total nickel contents.		
					Magnetic portion.	Feebly magnetic.	Non-magnetic.
92·95%	Ni 1·30 Fe 58·27 S 40·43	2·09%	4·96%	23·16 33·92 42·92	58·01%	7·60%	34·39%

Magnetic experiments by D. H. Browne.

A short time after (1893), David H. Browne (¹) contributed the most valuable article on the question of the magnetic separation of these ores which had yet appeared, showing the existence of a rich nickel-iron-sulphide, almost identical in chemical composition with pentlandite, which formed the non-magnetic portion of the separation. In the same article, Mr. Browne questions not only the validity of Dr. Emmens conclusions, as 'hasty generalizations from insufficient premises', but points out, that 'he has never yet found the non-magnetic residue of the analysis given by Dr. Emmens.'

Browne's criticism of Dr. Emmens' results.

Source of material separated by Browne.

The material selected for experimental purposes by Mr. Browne, consisted of carefully hand-picked nickeliferous pyrrhotitite, from the Copper Cliff, Stobie and Evans mines, altogether free from gangue, and with no copper, or at the most, only traces of this metal. He mentions that the samples were crushed to pass a 60-mesh sieve, experiment having shown that a very fine powder did not yield such perfect separations. The following tables show, in brief form, the results obtained :—

Preparation of material to be separated.

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(1) "Engineering and Mining Journal", Dec. 2, 1893. page 566.

COPPER CLIFF MINE, (SEVENTH LEVEL.) PICKED NICKEL ORE.

Percentages and composition of separated products.

Analysis of total ore.	Magnetic.	Analysis.	Non-magnetic.	Analysis.	Nickel in magnetic pyrrhotite.	Nickel in non-magnetic pentlandite.
Cu........ 0·00	78·6%	0·00	21·4%	0·00	34·00%	66·00%
Ni.........11·00		4·62		35·05		
Fe.........50·40		55·70		29·80		
S...........38·01		38·58		34·35		

STOBIE MINE, PICKED NICKEL ORE.

Cu........ 0·00	97·175%	0·00	2·825%	0·00	72·00%	28·00%
Ni......... 2·75		2·15		34·70		
Fe....... 58·00		57·00		29·90		
S...........35·35		36·10		33·90		

EVANS MINE, PICKED NICKEL ORE.

Cu..........trace	84·04%	0·00	15·96%	0	35·47%	64·53%
Ni......... 9 02		3·82		34·12		
Fe.........51·50		56·00		29·95		
S...........39·28		40·18		35·43		

Magnetic work by J. N. Judson.

Samples obtained from Copper Cliff.

Percentages and composition of the separated portions.

In 1900, Mr. J. N. Judson, of the Wetherill Separating Company, carried on an extensive series of experiments, an abstract of the results, accompanying Mr. C. W. Dickson's paper, on 'The Ore Deposits of Sudbury, Ontario'. (1) The material experimented with, consisted of nearly pure pyrrhotite from Copper Cliff, containing by analysis, nickel 3·14, copper 0·42, iron 49·78 per cent. The results showed, that with a current strength of one ampère, on material crushed to 30-mesh, 90·11 per cent of the total sample was magnetic, and this contained 2·46 per cent of nickel or the equivalent of 70·58 per cent of the total nickel in the original pyrrhotite, and 0·22 per cent copper, or the equivalent of 47·48 per cent of the total amount of this metal in the original sample. The remaining, non-magnetic portion, forming 9·89 per cent of the total sample, contained 9·33 per cent nickel and 2·21 per cent copper or 29·42 per cent and 52·52 per cent of the total of these metals, respectively, in the original sample. The other trials, with samples of the same material, crushed to pass a 60-mesh, at ¼ ampère, showed 86·22 per cent was magnetic and contained 1·92 per cent of nickel. The remaining 13·78 per cent or non-magnetic portion was a comparatively rich nickel ore, but the losses in the magnetic portion were so great, that he concluded that a commercial separation, by means of magnetism, was out of the question.

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(1) Trans. Amer. Inst. Min. Eng. (Albany Meeting), 1903.

Magnetic separations by C.W.Dickson.

During the winter sessions of 1901-1902, and 1902-1903, Mr. C. W. Dickson, a post-graduate student at Columbia University, carried on a series of experiments, by means of magnetism, in order to determine, as near as possible, how much of the nickel occurs as a separate mineral, and how much, if any, replaces iron, and also to ascertain the composition of the nickel mineral.

Preparation of material.

A number of representative samples of pyrrhotite were ground to pass through 100 mesh, and the non-magnetic portion was removed, as completely as possible, by repeated treatments with a small horseshoe magnet. The nickel present in the original samples, is given umder I, and that, of the magnetic concentrates, under II.

Exhaustive trials to eliminate last traces of nickel from pyrrhotite.

In the second experiment, the original samples were coarsely crushed, and the magnetic portion was sized between 40 and 60-mesh, then freed, as well as possible, from non-magnetic material, crushed between 60 and 80-mesh, and again concentrated By successive treatments, the mineral was finally reduced to fine powder. The ultimate product was then assayed for nickel, and as shown under III, the nickel was much reduced in quantity, but not entirely eliminated.

In the third experiment, to see if it was possible to still further reduce the nickel contents, a number of samples were very carefully prepared. They were coarsely crushed, and the purest mineral selected.

Composition of original sample and separated portions.

This was crushed to pass through 10 on 20-mesh, and the finest material rejected. All the non-magnetic portion was eliminated, and the concentrate was then crushed to 20 on 40-mesh, the finer part being again rejected. The operations were repeated until the ore was finally ground in an agate mortar, the non-magnetic part being very carefully removed each time. The nickel in the final concentrate is given under IV.

Location.	I. Ni & Co	II. Ni.	III. Ni.	IV. Ni.	Description of sample.
1. Elsie mine........	2.44	2·22	0·98	....	Fine-grained pyrrhotite.
2. Stobie mine	3.05	2·14	0.68	....	" " "
3. Frood mine	2.40	2·07	1·05	0·65	Coarse " "
4. Mount Nickel mine.	3·06	2·14	0·75	0·70	Medium " "
5. Copper Cliff No. 2 mine...	4·00	2·00	0·70	....	Coarse " "
6. Copper Cliff No. 4 mine...	3·30	2·32	0·83	....	" " "
7 (a.) Creightonmine.........	2·32	2·25	1·20	0·70	" " "
7 (b.) Creighton mine........	4·15	...	....	0·45	Fine " "
8. Gertrude mine..	4·00	2·30	1.10	....	Massive pyrrhotite.
9. Victoria mine......	3·40	2·46	0·80	....	Fine-grained pyrrhotite.

Nickel does not replace iron in pyrrhotite.

As stated by Mr. Dickson, the results show in the most conclusive manner, that even in the lower grades of pyrrhotite, the nickel is not present, as replacing part of the iron in the pyrrhotite, but exists as a separate mineral. The fact, that all the nickel could not be eliminated by the methods used, does not indicate, that even the small amount that remained was an essential part of the pyrrhotite, as several factors enter which render its complete removal practically impossible. In the first place, the nickel mineral is very intimately associated with the magnetic pyrrhotite and even a minute adhering fragment of the latter, will cause it to be carried over with the magnetic portion. It must also be noted, that the nickel mineral itself is slightly magnetic and in the form of a fine powder, is attracted by even a small magnet.

Explanation of presence of nickel in magnetic portion.

Magnetic work by W. M. Ogilvie for Geological Survey Dept.

The magnetic experiments, in connection with the present work, were carried on by Mr. W. M. Ogilvie, B. A. Sc., by means of a Wetherill magnetic separator of the ordinary type, in the mining laboratories of McGill University, the authorities, with the recommendation and approval of Dr. J. B. Porter, having kindly placed the machine at the disposal of the writer, for a considerable period, during the winter of 1901-1902. The samples selected, consisted of the richer grades of ore in use at the different mines. Such samples were obtained from the Creighton, Victoria, Cryderman and Mount Nickel mines, the Tough and Stobie property, in Levack township, and the Cochrane property, near Blue lake, on the Northern Nickel Range. It is to be regretted, that the chemical analyses could not be undertaken while the experiments were in progress, as otherwise much more important results could have been obtained. The voltage of the current employed was 110 and the strength of the current was varied according to the magnetic permeability of the different samples. The least magnetic of the material, was that obtained from the Creighton mine, and with such material, a current as high as 15 ampères was employed, while the pyrrhotite from the Cochrane property, on the Northern Nickel Range, was so strongly magnetic, that much weaker currents had to be used, the greatest reaching a strength of only 1.5 ampères.

Selection and location of samples.

Strength of magnetic current.

Creighton mine ore least magnetic.

Preparation of material for separation

In the case of the Creighton mine, the original sample weighing 36 pounds, was divided into two products, according to the size of grain obtained by crushing. The first product was obtained by passing the powdered mineral through a 40-mesh sieve, and catching it on a 100-mesh sieve, this part weighing 21 pounds. The second product, 15 pounds, was made up of the finer material which passed through the

Composition of original samples of Creighton mine ore.

Percentage of separated products.

Assays by Mr. Donald Locke.

Loss in magnetic portion too serious to be neglected.

Division of copper contents.

Separation of gangue.

100-mesh sieve. The coarser phase of the original sample gave the following analysis, insoluble 2.28, copper 0·72, nickel 5·31 and sulphur 34.28 per cent. The composition of the finer material was, insoluble 2·49, copper 1·20, nickel 4·87 and sulphur 34·67. Each of these two original samples, was divided into three equal portions, and subjected to magnetic currents of 1·5, 3·8 and 15 ampères respectively. By means of the magnetic current, each of these three portions was again subdivided into three grades, which may be designated as 'magnetic'; 'feebly magnetic' and 'non-magnetic'. The coarser material showed that the magnetic portion varied from 86·3 to 90·2 per cent of the whole sample, with a loss of 2·4 to 9·7 per cent in handling, which loss, however, could be over come, while the feebly magnetic portion contained from 4·2 to 8·6 per cent, and the non-magnetic from 1·3 to 2·7 per cent. In the finer material, the magnetic portions varied from 74·6 to 78·3 per cent, the feebly magnetic from 2·3 to 10·9 per cent, while the non-magnetic varied from 4.1 to 8 per cent. The loss, in the case of the fines was very great, owing to the dust adhering to the belts, the percentages of such loss varying from 9·2 to 11·4 per cent. Assays of all the separate products from the Creighton mine were made by Mr. Donald Locke, who for a short time was attached to this Department as assayer and metallurgist, but certain unexplained discrepancies in the results, will prevent, at present, the publication of all the details of the chemical investigation. In this connection, however, it may be sufficent to state that a very rich nickel ore was always obtained, the greater part of which was contained in the feebly magnetic portion, although a small proportion was carried over into the tailings or non-magnetic portion. The loss, however, in the magnetic portion, amounting to from 40 to over 50 per cent of the total nickel present in the original ore, was too serious to be disregarded. In addition to the nickel present, the magnetic part also contained from 28 to 48 per cent of the total amount of copper present in the original ore, while from 16 to 18 per cent is contained in the feebly magnetic part, and the remainder is carried over with a large proportion of the gangue into the non-magnetic residue, which is really a very rich copper concentrate, some of the assays showing as high as 28·38 per cent of this metal. The proportion of gangue present in the non-magnetic residue, generally amounts to about one-third of the total product.

Fine material free from dust gives best separation.

The best separation is effected on the fine material, although the presence of dust must be avoided, as this clings to and fouls the belts. The stronger the current, the greater the proportion of nickel remaining in the magnetic portion, while, at the same time, although the total amount of nickel present in the feebly and non-magnetic portions is less, the assay value of such products is much higher, and some of these, which were examined in detail, consisted almost wholly of pentlandite, with intermixed chalcopyrite. Thus, the feebly magnetic product of the fine material, obtained by using a current of 3·9 ampères with only one trial. showed, on analysis, the following composition, insoluble 5·81, copper 1.52, iron 30·41, nickel 30·01, sulphur 33·56 per cent. Knowing the composition of the pentlandite and chalcopyrite, and distributing the above constituents in their proper proportions in these minerals, we find that this product consists of chalcopyrite and pentlandite in the ratio of 1 : 21. In the same way the non-magnetic product obtained by using a current of 1·5 ampères on this fine material and from which most of the gangue had been removed by means of hydraulic separation, showed, by analysis, the following composition, insoluble 2.66, copper 3·58, iron 30·01, nickel 30·36 and sulphur 33·77 per cent. This product is made up of chalcopyrite and pentlandite in the proportion of 1 : 7.

Composition of feebly magnetic portions.

Proportions of pentlandite and chalcopyrite.

Composition of non-magnetic portion.

In the Victoria mine's separation, the ore was much more strongly magnetic, and the currents employed were only 0 2 and 1.5 ampères. The magnetic portion varied from 86·4 to 90.6 per cent on the coarser material, while with the fine material, using a current of 0·2 and 1·2 ampères, the magnetic part varied from 71·4 to 86·7 per cent. The feebly magnetic part never exceeded 2·1 per cent and in one case was as low as 0·5 per cent. No assays of these products, however, have been made, as the results obtained in the case of the Creighton mine, although of great scientific and practical interest, demonstrated rather clearly that under present conditions, an economic and commercial separation of these ores is out of the question.

Percentages of separated products in Victoria mine ore.

The Cryderman mine ore is also more magnetic than the Creighton mine, although less so than the Victoria. The original sample, on which the experiment was conducted weighed 30 pounds. This was divided into two portions, according to size, one portion consisting of crushed ore which passed through a 40-mesh and was caught on a 100-mesh sieve and finer material consisting of ore which passed through the 100-mesh sieve. The current used had a strength of 0·2, 1·5 and 4 ampères respectively. The magnetic portion of the coarser product varied from 75 to 85·6 per cent, the feeble magnetic from 2 to 7·7 per cent and the non-magnetic from 1·9 to 2·3 per cent. There was no loss using the 0·2 and 1·5 ampères current but with the 4 ampères current the loss was 4·8 per cent. With the finer material the magnetic part varied from 65·6 to 71·8 per cent, although the loss of 10·9 per cent

Cryderman mine ore more magnetic than that from Creighton.

Preparation of material and methods of separation.

Percentages of separated products.

belongs very largely to the first mentioned amount. The feebly magnetic part varied from 1·6 per cent to 17·2 per cent, the latter amount being obtained with the 4 ampères current, while the non-magnetic varied from 6·3 to 28·1 per cent.

Magnetic separation of Nickel Mountain mine ore.

The magnetic separation of the ore from the Nickel Mountain mine was effected by using currents having a strength of 1·5, 3·8 and 13·5 ampères respectively. The original simple weighed 63 pounds. The magnetic part of the coarser product (through 40-mesh on 100-mesh), varied from 91·2 to 92·5 per cent with losses of 0·9 and 2·5 per cent respectively, the feebly magnetic from 4·1 to 4·4 per cent, and the non-magnetic from 1·2 to 3·8 per cent. The losses varied from 4 to 5·7 per cent and are accounted for by the fact that the fine material has a great tendency to stick to the belts. Also the cross belts were given their maximum velocity to effect the best separation.

Percentages of separated portions.

Magnetic separation of of Levack ore.

The original sample from the Levack property (Tough and Stobie's), weighing 24 pounds was crushed in the same way as the above, and the magnetic currents used had a strength respectively of 0·2, 1·5 and 3·8 ampères. The magnetic portion varied from 92·5 to 96.3 per cent, with losses belonging chiefly to this part of 1·9 to 2·5 per cent, the feebly magnetic from 1.3 to 3·8 per cent and the non-magnetic from 1·3 to 2·5 per cent. With the fine product, the magnetic portion varied from 91·6 to 93·8, with a loss in one instance of 1·9 per cent, the feebly magnetic from 1·1 to 2·1 per cent, and the non-magnetic from 5·2 to 6·3 per cent.

Percentages of separated products.

Magnetic separation of pyrrhotite from North Nickel Range.

The pyrrhotite from the Cochrane property on the Northern Nickel Range is very strongly magnetic and the current used had a strength of 0·2 and 1·5 ampères. The magnetic portion of the coarser product varied from 85·3 to 89 per cent, with a loss of 1·4 to 2·8 per cent, the feebly magnetic 1 to 4·8 per cent and the non-magnetic from 4·8 to 10.9 per cent. With the finer material, the magnetic portion varied from 77.7 to 83 per cent, the feebly magnetic from 0·8 to 4·1 per cent and the non-magnetic from 15·2 to 18·2 per cent.

Wetherill separator very efficient.

The various factors which enter into the construction of the Wetherill magnetic separator suggested, at the the outset, that by its employment, it might be possible to accomplish a separation on a commercial basis, which, at the same time, would be much more thorough and complete, than any previously recorded attempts, making use of different types of hand magnets. Thus, it was possible on this machine, not only to vary at will the strength of the magnetic current, to be used, but also to make any required adjustment in the distance between the two magnets, while, at the same time, the speed of the

Various adjustments available.

Expectations from separation work.

belts was under complete control. With these refinements or aids to efficient separation, it was hoped to make such a thorough division of the products, that the nickel present in the magnetic portion would constitute such a small proportion of the whole, as to render this product of no commercial value, and thus, at one simple operation, get rid of about 80 per cent of practically barren ore. At the same time, it was believed that the feebly and non-magnetic portions would contain by far the larger proportion of both the nickel and copper.

Trials disappointing and so far of no great practical importance.

The preliminary trials of the Creighton mine ore, and assays of the separated products were disappointing, as they showed most conclusively that an efficient and economical separation by this method was impossible. It was, therefore, considered unwise to analyze the products from the other mines, although the main facts in connection with these separations have been mentioned.

Dickson and Judson both conclude that magnetic separation is a commercial impossibility.

About the same time, Mr. C. W. Dickson published the results of his magnetic experiments, which gave further emphasis to this conclusion. Mr. Dickson's final utterance on this subject, published in 1903, also contained a summary of Mr. J. N. Judson's results, to which reference has already been made, all tending to show that the removal on a commercial scale of the nickel from the pyrrhotite, by magnetic methods, is, in the light of our present experience, an impossibility. On the other hand, the fact that all of the nickel cannot be eliminated from the pyrrhotite, does not prove that even the portion remaining, occurs as a replacement of an equal amount of iron, in chemical combination. Examination under the microscope, reveals the fact that even the smallest grains of sulphide material, are often made up of intricate intergrowths of chalcopyrite and pyrrhotite, which minerals, moreover, can be distinguished from one another by the use of reflected light. Such an intimate relationship, doubtless, obtains in the case of the pyrrhotite and pentlandite, although this could not be proved, as these minerals cannot be separately recognized under the microscope. In addition, a large proportion, at least, of the pentlandite, is itself feebly magnetic, and this is apt to remain with the pyrrhotite.

Sulphides intricately intergrown with one another as shown by microscope.

Difficulties of obtaining pure product by magnetic methods.

The difficulty of obtaining an absolutely pure product, even of minerals of widely different magnetic permeability, is well known to all who have carried on experiments in magnetic separation, so that it is not surprising, that the magnetic portion of the separated sulphide, always contains an appreciable amount of nickel. In the light of our present experience, it is safe to say that the nickel is doubtless present as very minute grains of pentlandite embedded in or adhering to the grains of pyrrhotite. The fact that material originally containing 5·31 per cent of nickel, with the application of a current of 1.5 amperes on material crushed, to only pass through a 40-mesh sieve can, at one operation, be separated into a magnetic product containing only 1·48 per cent of nickel, while this, in turn, by successive grinding and magnetic treatment, can be ultimately forced to give a product which contains less than 0·50 per cent of nickel, is in itself sufficient proof, for regarding all the nickel in these Sudbury ores as occurring in the form of a distinct sulphide, chiefly pentlandite. With all of the foregoing results we may well pause and repeat with Dickson the question, 'Is there such a thing as a true nickeliferous pyrrhotite?' and we might even extend it and ask, is there such a thing as a true nickeliferous pyrite? The matter is still open for further investigation, although at the present stage, the 'onus probandi' rests with those chemists and mineralogists, who are still wedded to the old idea. A most convincing proof might be possible, by repeated magnetic treatment of some of the masses of pyrrhotite occuring in central Ontario, which are known to contain from 0·05 to 0·23 per cent of nickel. Any enrichment of the feebly magnetic or non-magnetic product obtained from the separation of such material, would no doubt furnish the most ample proof, which even the most skeptical would be forced to accept.

Proof that all of the nickel is present as pentlandite.

Is there a true nickeliferous pyrrhotite or pyrite?

More experiments needed and suggestions for their undertaking.

LOCATION OF PYRRHOTITE DEPOSITS BY MAGNETOMETRIC MEASUREMENTS.

The magnetic permeability of pyrrhotite early suggested the employment of magnetic instruments, to determine the location of valuable deposits of this nickel bearing sulphide in the Sudbury District. All the earlier measurements, however, were made by means of the ordinary dip-needle and the observers were content to obtain such data as would enable them to form a rough judgment of the approximate area underlaid by rocks containing more or less of the magnetic pyrrhotite, although this mineral might be so sparsely disseminated as to be of no economic importance.

Early employment of dip needle to locate pyrrhotite deposits in Sudbury District.

In 1901, however, it was decided by the Mond Nickel Company, to inaugurate a more extensive and elaborate system of magnetic surveying, not only in examining the properties they had already purchased, but also in determining the probable value of other nickel properties which were known to be in the market. It was realized that such delicate instruments as the Thalen-Tiberg magnetometer, in the hands of experts who had been trained in the Swedish methods, would yield data in regard to the location and extent of workable deposits of pyrrhotite,

Extensive magnetic surveying by Mond Nickel Company.

Employment of Swedish instruments and experts.

which would enable a very close estimate to be formed of their commercial value. Early in the spring of 1901, Messrs. Karl Köjer and Erik Nyström, mining engineers of Stockholm, Sweden, and pupils of the well known Professor Nordenström were engaged. Mr. Köjer only stayed about a month, but Mr. Nyström was employed for the greater portions of the two seasons of 1901 and 1902, in making detailed magnetic surveys of various mining locations and mines in this district. Most of the lots in the vicinity of the main shaft of the Victoria mines were thus minutely examined, and later, other properties such as the Murray, Lady Violet, Mount Nickel, Beatrice and Cryderman mines were also similarly treated. A magnetic survey was also made of the Cochrane property on the Northern Nickel Range. It is impossible to get the details of the results of this work, as the maps which were prepared with great care, are the property of the Mond Nickel Company, the information being regarded as of a confidential nature.

Magnetic work by Köjer and Nyström.

Deposits magnetically surveyed.

The value of such work, however, when properly undertaken, is beyond all doubt, although, considerably more care and expense is necessary, than is the case with magnetite. Speaking roughly the magnetic permeability of magnetite is about five times as great as pyrrhotite although this latter mineral varies very greatly in this respect. It is, therefore, imperative, that the lines along which the magnetic observations are made, should be correspondingly closer together. In most of the detailed work undertaken by the Mond Nickel Company these lines were only separated by intervals of 20 feet, while, in some special cases, where fuller information was desired or necessary, a distance of only 10 feet intervened between the various observation stations. For some time, commencing in 1902, Mr. Thomas A. Edison carried on rather extensive magnetic surveying in the area between Sudbury and Wanapitei lake, with a view of discovering new deposits of nickel ore. The efforts of the several parties engaged in this work, are stated to have met with a considerable degree of success, as on the strength of the information obtained, various mining locations were applied for. Messrs. J. A. Robert and G. F. Kay, have also conducted magnetic surveys under the auspices of the Lake Superior Power Company. The publication of Dr. Haanel's report (1) 'On the Location and Examination of Magnetic Ore Deposits by Magnetometric Measurements' should stimulate this method of inquiry, not only in connection with these pyrrhotite deposits, but also as regards our magnetic iron deposits. It is the only detailed account of the Swedish

Relative magnetic permeability of pyrrhotite.

Methods employed in magnetic surveying.

Work by Thomas A. Edison and assistants.

Magnetic surveys made by Robert and Kay for Lake Superior Power Co.

Report by Dr. Haanel.

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(1) Published by the Department of Interior, Ottawa, Canada.

method which has yet appeared in the English language. With the exception of magnetic observations to assist in the geological mapping, chiefly, of the iron formations and associated rocks of the Lake Superior district, details of which are furnished by Prof. H. L. Smyth (2), no very extensive use of magnetic instruments has been made in any other country outside of Sweden. The Swedish instruments may be obtained from J. Fr. Berg, instrument maker, Stockholm, and are the most perfect and suitable for the work, which have yet been manufactured. All necessary descriptions and information in regard to their operation may be obtained by consulting Dr. Haanel's work which he hopes may be of service to the mining profession.

Use of magnetic surveying by Prof. H. L. Smyth.

Where Swedish instruments may be purchased.

CLASSIFICATION AND GENESIS OF NICKEL ORES.

Mineralogically, the ores of nickel may be divided into eight classes, as follows: 1. Sulphides; 2. Arsenides and sulph-arsenides; 3. sulph-antimonides; 4. Sulpho-bismuthides; 5. Tellurides. 6. Silicates; 7. Oxides and Salts; 8. Carbonates.

Mineralogical classification of nickel ores.

Many of the nickel minerals, included under these divisions, are unimportant in an economic sense, and Vogt (1) has shown that all of those which are commercially valuable, fall naturally into three main groups.

Vogt's classification of nickel ores into three groups.

1. Ores containing arsenic and antimony, with or without bismuth, such as niccolite, gersdorffite, chloanthite, &c.

Ores containing arsenic and antimony.

2. Sulphide ores (without arsenic), as for example, nickeliferous pyrrhotite and pyrite, pentlandite, polydymite, millerite, &c.

Sulphide ores

3. Silicated nickel ores, such as genthite, garnierite, &c.

Silicates of nickel.

The arsenides and sulph-arsenides, belonging to the first group, occur principally in veins, as for instance, the old and well known metalliferous lodes of Saxon and Hungary; Mine la Motte and Bonne Terre, in Missouri; the Gem mine in Fremont county, Colorado; the Macdonell or Gersdorffite mine, in the Sudbury District, Ont.; and the recently discovered deposits near Haileybury on the west side of Lake Timiskaming, Ontario.

Principal localities where arsenide ores are found.

By far the largest deposits, belonging to the second group, are the nickel-copper sulphide ores, of the Sudbury District, in Canada, which are the subject of the present bulletin, but Norway has, for many years, operated, on a large scale, precisely similar concentrations. Other

Chief localities where sulphide ores are found.

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(2) Trans. Amer. Inst. Min. Eng. Vol. XXVI, pp. 640-709.

(1) Zeit fur Prak. Geol., 1893.

closely related ore bodies have also been worked as mines, as at Varallo, in Piedmont, Italy and at Lancaster Gap in Pennsylvania. The deposits which have been partially developed and worked, near St. Stephen, in the Province of New Brunswick, Canada, are also apparently of the same nature. The most celebrated and extensive of the deposits, representative of the third group, are those of New Caledonia. Important bodies, however, of similar silicates, are known to occur, and have been developed, to some extent, near Riddle's, in Douglas county, Oregon, and near Webster, the capital of Jackson county, in western North Carolina.

Where nickel silicates occur.

Geological associations and origin of arsenides and sulph-arsenides of nickel.

The veins of the first group occur, either, penetrating, or in intimate connection with eruptive rocks of the peridotite or gabbro type, and are generally found in the more decomposed or altered portions. These basic igneous rocks, as is well known, contain appreciable quantities of nickel, as a normal constituent. The extremely rich nickel ore, contained in these veins, has therefore, evidently been derived from the leaching out of the nickel from the neighboring rock, during certain processes of alteration, to which it has been subjected.

Sulphides, direct result of magmatic differentation, modified by some secondary action.

The method of formation of the sulphide deposits of the second group, typified by the Sudbury deposits, has already been discussed at length, and the conclusion reached, that they are the direct product of the differentiation of a basic igneous magma, modified, to some extent, by processes, which are usually grouped together under the designation of secondary action.

Geological associations of silicates of nickel.

The silicates of nickel are always confined to areas underlaid by intrusive masses of non-felspathic basic magnesian rocks, of the peridotite family, the several varietal forms of which are distinguished from one another by the names of dunite, saxonite, websterite and eherzolite These rocks are always more or less decomposed to a serpentinous material, so that the type of rock with which these deposits occur, is usually described as serpentine.

Mode of occurrence of silicates of nickel.

The ore rarely crops out at the surface, but is covered with a thick mantle of decomposed material, from which most, if not all, of the nickel has been leached, to be concentrated in places a few feet lower down. This covering or soil is very highly ferruginous, with occasional large 'chert' fragments lying about. These pseudo-boulders of so-called chert, are considered a favourable sign, in prospecting for the ore bodies, for they invariably indicate the presence of the peridotite beneath. They really represent residual portions of the peridotite, which escaped the wholesale decomposition, on account of their being held together by an intricate series of quartz veinlets, the interstices of which are

Explanation of occurrence of 'chert' fragments.

occupied by only partially decomposed peridotite. The surface mantle or soil usually varies from nothing, up to a few feet, when it gives place, gradually, to a loose, brownish material, representing the decomposition of the peridotite 'in situ.' This usually shows abundant, but small and intricate veins and veinlets of the greenish silicate of nickel and magnesium, often with abundant scales of chrome mica. In places, irregular fissures and cavities, often of considerable size, are occupied by rather pure silicate material. This brownish, loose material gives place, in turn, to a brownish, soft, friable rock, filled with smaller but harder and rich veinlets of the nickel silicate, while this, again, is replaced further down, by the unaltered peridotite, which, it is believed, will contain little or none of the silicate concentrations.

Nickel bearing gossan.

Analyses of the associated dunite or websterite, from the North Carolina occurrences, show the undecomposed rock to contain, from 0·15 to 0·35 per cent of nickel oxide, while the saxonite, in which the Oregon occurrences are developed, contains, according to Diller, 0·10 per cent of nickel oxide, while the olivine itself, of which the rock is mainly composed, contains 0·26 per cent of nickel oxide. This is a very usual occurrence, and the undecomposed peridotite of New Caledonia often contains as high as 1 per cent of nickel oxide. Similar rocks, from the Eastern Townships of Canada, show the presence of 0·15 to 0·26 per cent of oxide of nickel, without cobalt while the associated chromic iron ore also contains 0·22 per cent of oxide of nickel, with distinct traces of cobalt. It is almost impossible to collect any of the brownish material, resulting from the decomposition of these peridotites, without finding an appreciable amount of nickel present. It appears certain, therefore, that the nickel has been leached out of the surrounding rock, and redeposited along with silica and magnesia in all available cracks and interspaces. The peridotite is always readily decomposed under ordinary conditions of atmospheric decay, the magnesia being the first ingredient to be carried away in the form of a carbonate. This is followed by the silica and nickel, which is redeposited at lower levels and in suitable places. The result of such an origin, will be the occurrence, at these several localities mentioned, of comparatively shallow deposits, their downward extension, depending almost entirely on the depth to which decomposition has proceeded. On the other hand, the ease with which many of these deposits may be mined, and the large amount of comparatively rich and desirable nickel ore, which may be thus secured, make them particularly attractive.

Determinations for nickel in peridotite rocks associated with silicated ores.

Origin of silicated ores of nickel.

Comparatively shallow deposits.

Attractive deposits.

DISTRIBUTION OF NICKEL ORES.

Ores of nickel of world wide distribution but rarely of economic importance.

Ores of nickel are much more evenly and abundantly distributed over the whole world than is generally supposed, but in only a few countries are the deposits of such dimensions, as to warrant their development as working mines, and, at the present day, the mines of New Caledonia, and those of Sudbury produce almost the whole of the world's supply of nickel.

Vein deposits of Saxony and Hungary.

Small quantities of the arsenides and sulph-arsenides of nickel are found in association with ores of silver, lead, bismuth and cobalt, in the well known veins of Saxony and Hungary. As a rule, however, this nickel may be regarded as a by-product obtained in the refining of these ores, and although valuable, it forms a comparatively small proportion in comparison with the other metals present.

Nickel ores in Sweden, Finland and especially Norway.

Nickel in Scotland, Ireland and Wales.

Nickel also occurs in Sweden and Finland, and the famous deposits of Norway, for many years produced a comparatively large proportion of the nickel of the world. Nickel is also known to occur in Scotland while the serpentines of the west of Ireland, and those of Cornwall, all contain a little nickel associated with them.

Nickel in Russia.

Nickel in U.S.A.

Nickel at Mine la Motte.

Nickel in Colorado.

Nickel in California.

Nickel in Connecticut.

In Russia, nickel has been reported from Rewdinsk and Zanghesour. The most celebrated deposit of nickel in the United States is at the Gap mine, in Lancaster Co., Pennsylvania, but this mine suspended operations in 1891. The domestic production of nickel in the United States is, at present, all derived as a by-product, from the treatment of the lead ores, which are found in the mineralized portion of the sedimentary limestones at Mine la Motte, Missouri. Very rich nickel ore has been found in the 'Gem mine' in Fremont Co., Colorado. Nickel minerals are also known to occur at other localities in this state, as for example, in the hornblendic rock near Salida, associated with copper, and also in small quantities, in some of the ores from the Leadville region. The occurrence of nickel has also been reported from several places in California. At the Kelsey mine, in Los Angeles county, nickel and cobalt are found in the form of arsenates, together with silver-glance and native silver, in a fissure vein, in close relation with a dyke rock, probably diorite. The associated ores contain 7 to 15 per cent cobalt, and 2 to 3 per cent nickel, and 1,000 to 1,400 ounces of silver per ton. (1) Nickel also occurs at the cobalt mines near Chatham, Connecticut. Some important bodies are known to exist in Nevada but these have not been extensively developed. Nickel ores are also reported from Idaho, Arizona and New Mexico. Rich ores of nickel also occur in the copper district south of Lake Superior. The most important deposits of nickel ore at present known to exist in the United States, are the silicates of North Carolina and Oregon, to which more detailed references will be made.

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(1) Proc. Col. Sci. Soc. Vol. IV, 1891-93, pp. 419-20.

Nickel in Idaho, Arizona, New Mexico.

In Canada, the distribution of the nickel deposits occurring at Sudbury, have already been described, but important bodies of similar sulphide material are also known to occur, and have undergone preliminary development at St. Stephen, New Brunswick. Other occurrences are reported from British Columbia, and the Province of Quebec, but these are at present of no economic importance. In Newfoundland, rich nickel ore has been found in considerable quantities at the Union mine, at Tilt cove, in Notre Dame bay. Australia, New Zealand, South Africa and Chili, all contain deposits of nickel ore, but New Caledonia is the only formidable rival with which Sudbury has at present to deal.

Nickel ore near St. Stephen, N.B.

New Caledonia only possible rival of Sudbury.

NICKEL IN CANADA.

The Wallace mine, about a mile west of the mouth of the Whitefish river, on the north shore of Lake Huron, is of historic interest, as being the first place in which the presence of nickel was recognized in Canada. It was first opened as a copper mine, in 1847. During the season of 1848, this location was visited by Mr. Alex. Murray, Assistant Provincial Geologist, who reported on the geological associations and probable extent of the deposit. (1) This occurrence has also been described by Mr. C. W. Dickson (2), as consisting of pyrrhotite, pyrite and chalcopyrite, occurring at the junction of two small dykes of mica-diorite, which are intruded into the surrounding quartzites. The mining development work undertaken did not reveal any large body of ore, and although a considerable amount of copper ore was encountered, in assotion with a rich arsenical ore of nickel, the occurrence of the latter in very small veins, adjacent to the southern wall of the mine, did not encourage extensive mining operations, and the mine was accordingly soon abandoned. The material, obtained by Murray, in 1848, was handed to Dr. Hunt for analysis. This specimen, weighing forty-five ounces, is described by Dr. Hunt, as 'a steel grey arseniuret, the species of which I have not yet determined, with iron pyrites and pro-

Nickel first noticed in Canada at Wallace mine.

Description of Wallace mine deposit by C. W. Dickson.

No large body of ore.

Mine abandoned.

Description by Hunt of specimens collected by Murray in 1848.

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(1) Rep. of Progress, Geol. Surv. Can., 1848-49, pp. 42-45; also pp. 61-64; also Geol. of Canada, 1863, pp. 59-60, 506, 695, 737; also Min. Res. Ont., 1890, pp. 24, 67, 91 and 97.

(2) Trans. Amer. Inst. Min. Eng. 1903.

Character and chemical composition of ore of Wallace mine.

bably some arsenical sulphuret of iron.' The analysis of the whole mass, when powdered, gave the results under I. The first five substances making 59·30 per cent of the ore, are separated, as corresponding to the metallic portion of the mass, although, it is probable, that a portion of the iron is derived from the gangue. The cobalt equals about three parts in a thousand of the weight of the nickel. Removing the gangue, and re-calculating the remainder to 100, we get the results under II.

	I		II
Iron	24·78		41·79
Nickel (with a trace of cobalt)	8·26		13·93
Arsenic (mean of two determinations)	3·57		6·02
Sulphur	22·63		38·16
Copper	0·06		0·10
		59·30	100·00
Silica	28·40		
Carbonate of lime	4·00		
Magnesia	4·40		
Alumina	3·21		
		40·01	
		99·31	

Description and chemical composition of niccolite and domeykite of Michipicoten island.

Two ores of nickel are described by Dr. Hunt, (1) as occurring 'in a vein, cutting a bed of amygdaloid, on Michipicoten island, in Lake Superior. The first of these is a brittle, massive ore, associated with quartz and having a brilliant metallic lustre and a colour varying from tin-white to bronze-yellow. Its hardness is 5 and its specific gravity varies from 7·35 to 7·40. The mineral is variable in composition. The results of four analyses were as follows:

	I	II	III	IV
Arsenic	37·36	44·67	.....	.....
Copper	44·70	30·81	27·60	10·28
Nickel	17.03	24·55	27·29	36·39
Silver	.....	0·25	0·21	.....
Total	99·09	100·28		

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(1) Geol. of Can., 1863, pp. 506 and 737.

The above variable results are due to the material analyzed, consisting of a mixture, in different proportions, of niccolite (nickel 44·1 per cent and arsenic 55·9 per cent) and domeykite (copper 71·7 per cent and arsenic 28·3 per cent).

Description of occurrence and chemical composition of silicate of nickel of Michipicoten island.

The second ore, said to be from the same mine as the preceding, occurs as the gangue of native copper and native silver, which are scattered through it in grains. The material is amorphous, greenish-yellow or apple-green in colour, with a waxy lustre and a conchoidal fracture. It is very soft, polishing under the nail, and falling to pieces when immersed in water. It is decomposed by acids, and is found to be essentially a hydrated silicate of nickel. Under I, is an analysis of one specimen dried at 212° F. Under II, is an analysis of another specimen dried at a higher temperature. It contains, besides, traces of cobalt and copper, and appears to be identical with nickel-gymnite or genthite. Under III, is a partial analysis of a specimen, which contained small disseminated grains of the native metals.

	I	II	III
Silica	33·60	35·80	.....
Oxide of nickel	30·40	32·20	20·85
Protoxide of iron	2·25	.....	.....
Lime	4·09	.....	.....
Magnesia	3·55	.....	.....
Alumina	8·40	.....	.....
Water	17·10	12·20	.....
Cobalt	.....	traces	.....
Silver	.....	.....	2·55
Copper	.....	traces	18·51
	99·39		

Niccolite in Tuunder Bay District, Ont.

The arsenide of nickel (niccolite), has also been found at the 3 A mine, on lot 3 A, of the township of McGregor, in the District of Thunder Bay, Ont., where it occurs in somewhat large, nodular grains and bunches, together with native silver, of a similar form, freely disseminated through a gangue of calc-spar, with some quartz. (1)

Nickel in basic magnesian rocks of Province of Quebec.

Nickel is seldom or never absent from the magnesian rocks of the Eastern Townships, in the Province of Quebec, and the various serpentines, steatites, diallages, actinolites, etc., always contain small quantities of this metal, rarely, however, more than two or three thousandths. It has never yet been found in any considerable quantities, although the chromic iron ore from Ham, gave, on analysis, 0·22 per cent of oxide of nickel. (1). Dr. Harrington also found a small amount of nickel, in the serpentine, brought by Dr. Bell, from Pigeon lake, on the Montreal river, Ontario. (2)

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(1) Ann. Rep. Geol. Surv. Can. Vol. V, 1890-91, Part R, p. 47.

Nickel from Montreal river.

Orford Nickel mine.

Mining for nickel was, at one time, carried on at lot 6, con. XII., of the township of Orford, in the Province of Quebec, but operations had evidently been suspended for a considerable time, before the year 1883, when Mr. Willimott visited the locality. (3) The presence of nickel at this locality, had been known for a long time (4) but the deposit had not been opened up as a mine, until long after its discovery. The location, known as the Orford Nickel mine, was developed by means of two small shafts, sunk on what appears to be a large calcite vein, enclosing small transparent green crystals of chrome garnet, and often penetrated by long filaments of pyroxene, of a greenish or yellowish colour. The chrome garnet also forms large granular masses, holding sparingly disseminated, small, brass-like grains and crystals of millerite. The largest crystals, however, are generally found penetrating a beautiful cleavable variety of calcite, and often exceed three inches in length. The houses, mining buildings and smelting furnaces were abandoned in 1883, with the exception of one house, which was occupied by a caretaker.

Description of deposit.

Occurrence of millerite.

Mine abandoned before 1883.

Nickel from Joliette Co., Que.

A sample of iron pyrites, from the eleventh concession of the Seigniory of Daillebout, Joliette Co., in the Province of Quebec, yielded Dr. Hunt, 0·55 per cent of oxide of nickel (= 0·43 per cent of nickel) mixed with cobalt. (5)

Nickel bearing pyrite at St. Jerome.

A carefully picked sample of iron pyrites, occuring on lot 163 of the cadastral plan of St. Jerome, P.Q., was analyzed by Dr. Harrington and found to contain copper 0.05 per cent, cobalt 0.22 per cent and nickel 0.10 per cent. (6)

Pyrite with nickel and cobalt at N. Burgess, Ont.

Dr. Hunt mentions that a bronze-coloured, impalpable variety of iron pyrites, in irregular, reniform or globular masses, which occurs with copper pyrites, in the township of North Burgess, Ont., gave him on analysis, 3.47 per cent of cobalt and 2.21 per cent of nickel. (7)

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(1) Rep. of Progress, Geol. Surv. Can. 1853-56, pp. 435-474; also Geol. of Can. 1863, pp. 507 and 614.

(2) Ann. Rep. Geol. Surv. Can., 1876-77, p. 483.

(3) Rep. of Progress Geol. Surv. Can. 1880-82, Part G.G. p. 5.

(4) Geol. of Can., 1863, p. 738.

(5) Geol. of Can., 1863, p. 506.

(6) Rep. of Progress Geol. Surv. Can. 1876-77, p. 482.

(7) Rep. of Progress, Geol. Sur. Can. 1863-66, p. 217.

Pyrrhotite with nickel at Pic island, Lake Superior.

Dr. Adams analyzed a specimen of pyrrhotite, associated with a little chalcopyrite and sphalerite, with a small amount of intermingled chlorite, from Pic island, Lake Superior, and found it to contain 0.562 per cent of nickel and 0.138 per cent of cobalt. (¹)

Pyrite with nickel at Londonderry, N.S.

Dr. Hoffmann analyzed a specimen of iron pyrites, from Londonderry, N.S., which he found to contain 0.144 per cent of nickel and 0.813 per cent of cobalt. (²)

Occurrence of gersdorffite near Rossland, B.C.

Determinations for nickel.

Nickel has also been met with in British Columbia, at various localities, associated with pyrrhotite and other sulphides. Gersdorffite has been observed, in the form of small octahedral crystals, distributed through specimens which show an intimate association of massive pyrrhotite and chalcopyrite, from the Columbia-Kootanie property, one mile and a quarter northeast of the town of Rossland. The whole sample which weighed 6 lbs. 10 ozs. was analyzed by Mr. F. G. Wait (³) who found it to contain 0.65 per cent nickel, with traces of cobalt

St. Stephen deposits first described by Brumell.

Considerable interest has been manifested in the deposits nickeliferous pyrrhotite occurring near St. Stephen, N.B. These deposit were first visited and described by H. P. H. Brumell. (⁴) Dr. R.W Ells, who visited the localities, where these ore bodies occur during the summer of 1903, has furnished the following description. (⁵)

Description of nickel bearing rocks of St. Stephen, N.B., by Dr. Ells.

Age of nickel bearing rocks of St. Stephen.

The nickel bearing rocks of St. Stephen were specially examined, and found to consist of never intrusives, instead of the Laurentian granites, as at one time supposed. The rocks are chiefly of the gabbro type, which have penetrated and altered a series of black and gray slates, the age of which has also been a matter of much doubt. They were, at one time, supposed to be of Silurian age, but from the absence of fossils, this point has never been fully determined. As developed about the head of Oak bay, it was supposed, that here, they might be the equivalents of some portion of the primordial of the St. John area, but this point also has never been determined by finding fossils. On the geological map of the district, they are provisionally coloured Cambro-Silurian. They apparently underlie, conformably, the sandy

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(1) Ann. Rep. Geol. Surv. Can., 1880-82, Part H., p. 15.

(2) Ann. Rep. Geol. Surv. Can., 1874-75, p. 14 and Vol. V, 1890-91, Part R. p. 48.

(3) Ann. Rep. Geol. Surv. Can., Vol. IX, 1896, Part R. p. 15, 16 and 38.

(4) Ann. Rep. Geol. Surv. Can., Vol. IV, 1890-91, Part SS. pp. 112-114; also Vol. X, 1897 Part M. pp. 27-30.

(5) Summ. Rep. Geol. Surv. Can., 1903, pp. 156-159.

slates, which are regarded as Devonian and which occupy the northwest portion of the county, and on this basis, their age might be Upper Silurian.

Alteratiion of associated rocks.

They are extensively altered in many places, changing into mica and chiastolite schists, but these alterations are purely local, and caused by intrusions of the gabbro masses. They resemble, in certain points, pre-Cambrian schists, but not as a series. Further detailed examinations for fossils, will be required, to finally settle the question of their true horizon.

Nickel occurs in pyrrhotite at St. Stephen, N.B.

The nickel near St. Stephen, occurs in pyrrhotite, as at Sudbury, but the associated rocks are of a very different geological horizon from those of the latter district. The pyrrhotite is found in gabbro masses, which cut a series of slates, and have altered these extensively along the contacts. The mineral occurs, apparently, in pockety masses, which are probably quite local in character. The ore is found at a number of points, but attempts at mining for nickel have been made chiefly at two places, on what are known as the Rogers and Hall farms. The former is usually styled the Todd mine, the latter the Carroll mine.

Todd and Carroll mines.

Mining development work at Todd mine.

On the Rogers farm, considerable work, mostly of an exploratory nature, has been done. A shaft, 12 x 12, has been sunk for 24 feet, and three trenches have been cut, with depths ranging from three to eight feet, the principal one being rather more than two chains in length, on a course of S. 54° W., magnetic. In this trench, the ore is exposed for a little more than 30 feet along the line of excavation, the rest of the cut showing partly mixed ore and partly rock. The width of the ore body was not ascertained, as sufficient development work has not been done to decide this point.

Mining work undertaken at Carroll mine.

On Hall's lot, (Carroll mine), several shafts have been sunk, one of 77 feet, one of 14 feet and one of 12 feet. In addition, a bore-hole with a diamond drill, was carried down from the bottom of the deepest shaft, to a further depth of 163 feet. From information obtained from Mr. J Carroll, the first 40 feet of the main shaft was in ore, but from that point, to the bottom, the ore was mixed with rock.

Openings near edge of gabbro mass.

The formations at this place are practically the same as on the Todd area. The openings are apparently near the eastern edge of the gabbro mass, since altered slates are seen in close proximity.

An examination of the specimens collected from one of these deposits, about three miles north of St. Stephen, was conducted by Mr. R. A. Johnston, (1) who gives the following description.

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(1) Ann. Rep. Geol. Surv. Can., Vol. V., 1890-91, Part R, p. 39.

'The material consisted of pyrrhotite, through which was disseminated a little copper pyrites, and a very small amount of quartzose gangue.' A partial analysis gives the results under I, or calculated on the material free from all gangue, under II.

Description and partial analysis of ore from St. Stephen.

	I	II
Nickel	1·72%	1.82%
Cobalt	0·16%	0.17%
Copper	0·31%	0·33%

Pyrrhotite, in association with chalcopyrite, and a little magnetite, in a gangue of greenish-gray serpentine, obtained from Thompson's farm, St. Stephen, was partially analyzed by Dr. F. D. Adams. ([1]) The pyrrhotite constituted approximately, about one fourth, by weight, of the whole. The pyrrhotite, carefully freed from the associated minerals, was found to contain, nickel 0·923 per cent, and cobalt 0·394 per cent.

Association of pyrrhotite and partial analysis from Thompson's farm.

Partial analyses, by Mr. M. F. Connor, of this Department, were made of specimens, selected by Mr. R. A. A. Johnston, from both the Todd and the Carroll properties. The specimen from the Todd mine, consisting of nearly pure pyrrhotite, with a small proportion of intermixed chalcopyrite, and with about 10 per cent of gangue, gave nickel 1·38 per cent, and cobalt 0·21 per cent. The specimen from the Carroll mine, which was almost pure pyrrhotite, with very little chalcopyrite, and less than 5 per cent of gangue, gave nickel 1·35 per cent and cobalt 0·21 per cent.

Analyses of ore from Todd and Carroll mines.

It will thus be seen, that the ore is of lower grade than that generally met with and mined at Sudbury, so that, for the present, at any rate, unless large bodies are encountered, these deposits will not be able to compete with the much larger and richer deposits of Sudbury.

St. Stephen ore of lower grade than that of Sudbury.

The rocks, at all these places appear, to be very similar in character' and consist, for the most part, of a gabbro, varying from fine to some what coarse-grained. The presence of the pyrrhotite, is indicated by masses of gossan at the surface, and in places, the ore is largely mixed with rock. There does not appear to be any well defined contact of the ore body with the adjacent rock, and but little indication of a vein structure is visible. Outside of the ground covered by the trenches and pits, the surface shows the gossan cap at a number of points, with a thickness ranging from a few inches to several feet. From the fact that this capping shows at several places, east of the main trench, on the Rogers farm, it is probable, that masses of pyrrhotite will be found over a considerable area, but probably, in many, cases, so mixed

Geological association of pyrrhotite.

No well defined contact or vein structure.

Occurrence of gossan.

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(1) Ann. Rep. Geol. Surv. Can. 1880-82, Part H. p. 16.

with rock, that careful separation would be necessary after mining. The existence of these ore-bodies could be best proved by judicious boring with a diamond drill. The areas of gabbro are limited, and appear to rise, in dome-shaped masses, through the slate formation, at a number of places. In the present state of development of the district, but little information of a definite nature can be given as to future values.

Diamond drill operations recommended.

No very definite information yet available.

Pyrrhotite at Moore's mill.

At the location near Moore's mill, while the gabbro is seen at different points, the pyrrhotite appears to be disseminated in a mass of altered schistose slates. The ore here is, apparently, also of a low grade, and the extent of the deposit not large.

Nickel at Calumet island, Pontiac Co. Que.

Another locality, where mining for nickel has been undertaken, is on lots 11 and 12, range IX., of the township of Calumet (Calumet island), Pontiac county, in the Province of Quebec. (¹) The ore is mostly a pyrrhotite, containing both nickel and cobalt. The associated rocks are diorites, that cut a series of grey and rusty gneisses and crystalline limestones. A large knoll of the diorite, rises to the south of the ore bed, which has a thickness of about twelve feet, and between it, and the diorite mass, is a band of crystalline limestone. The ore itself is associated with another band of diorite, that apparently traverses grey gneiss, the latter being seen beneath, or to the north of the ore deposit. On the river, a short distance to the south of this mine, the formation is mostly a crystalline limestone, and the intrusions of diorite and granite, in this rock, can be readily seen. The band of pyrrhotite at the Cowen mine, dips to the south, at an angle of about 50°. A shaft has been sunk to a depth of about forty feet, and cross-cuts have been made, to test the width of the deposit.

Mode of occurrence and geological associations.

Cowen mine deposit.

Partial analysis of ore obtained from E. P. Cowen.

A compact massive pyrrhotite, through which was disseminated small quantities of quartzose gangue, handed to Dr. G. C. Hoffmann by Mr. E. P. Cowen, was partially analyzed by Mr. F. G. Wait, giving the results under I. The gangue constituted 4·30 per cent, by weight, of the whole; so that, neglecting this, the pure sulphide would give the results under II.

	I	II
Nickel	3·88%	4·06%
Cobalt	0·32%	0·33%

Other nickel bearing sulphides at Calumet Island.

A quartz-amphibolite, carrying a somewhat large quantity of pyrrhotite, some pyrite, a small quantity of chalcopyrite, and a very little zinc blende, was obtained from the southeast half of lot 6, range II, of

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(1) Ann. Rep. Geol. Surv. Can., Vol. XI., 1898, Part A p. 119.

the township of Calumet. The pyrrhotite, freed from all gangue and associated minerals, was found, by Mr. F. G. Wait, to contain nickel 1·48 per cent, with no cobalt. (1).

Cobaltiferous löllingite in Galway, Ont.

Cobaltiferous löllingite (diarsenide of iron), occurs on lot 16, concession XIV, of the township of Galway. The specimen was received by Dr. Hoffmann, from the late Mr. J. B. Campbell, on July 21, 1888. (2).

Association and physical character of löllingite.

The mineral, which was associated with a small quantity of pyrrhotite, and a little white translucent quartz, was massive and exhibited only in parts, and that but very indistinctly, any approach to crystalline structure. Colour, steel-grey; lustre, metallic; brittle; fracture uneven; streak, greyish black; specific gravity, after correction for a little included quartz at 15·5° C., 7·028.

Chemical analyses of löllingite by Johnston.

An analysis by Mr. R. A. A. Johnston, of carefully selected material, afforded the results under I. Deducting the gangue (silica), and re-calculating the remaining constituents to 100, we obtain the results under II.

	I	II
Arsenic	70·11	70·85
Sulphur	0·80	0·81
Iron	24·41	24·67
Cobalt	2·85	2·88
Nickel	0·78	0·79
Gangue (quartz)	1·69	.....
Totals	100·64	100·00

This mineral had not previously been identified in Canada, and, if found in quantity, would be of economic importance.

Cobalt, nickel, arsenic and silver ores appear.

The discovery of cobalt, nickel, arsenic and silver ores, on the west side of Lake Timiskaming, Ontario, was made public in November, 1903. The deposits were discovered during the building of the Timiskaming and Northern Ontario Ry., the road bed of this new government railway running almost over the top of the first of the deposits discovered. The deposits lie five miles south of the village of Haileybury, which is 106 miles north of North Bay, and 333 miles north of Toronto. At the time of Prof. Miller's (3) visit, from whose description the present information is obtained, four veins or deposits had been located, in the vicinity of a small body of water, known as

Lake Temiscaming discovery of deposits.

Examination of deposits by Prof W. G. Miller.

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(1) Ann. Rep. Geol. Surv. Can., Vol. XI, 1898, Part R p. 39.

(2) Ann. Rep. Geol. Surv. Can. Vol. VI, 1892-93, Part R p. 19 and 43.

(3) Eng. and Min. Jour., Vol. LXXVI, Dec 10, 1903, pp. 888-889: also Canadian Mining Review, Dec. 31st, 1903.

Location of deposits. Veins cut Upper Huronian rocks.

Presence of basis eruptives suspected but not recognized. Strike of veins.

Long lake, lying about half a mile south of the southern boundary of lots 8 and 9, con. I., of the township of Bucke. All of the veins cut through the slate and slate conglomerate, of the Upper Huronian. The presence of dykes or sheets of the darker coloured eruptives was suspected, but they were not definitely recognized. The slate and slate conglomerate have a slight dip, and the veins referred to, cut them almost vertically. The strike of the veins Nos. 1 and 3, is approximately northeast and southwest, that of 4, is east and west, that of 2, northwest and southeast.

Location and association of vein No. 1.

Ores consist principally of niccolite and smaltite with much native silver.

Presence of annabergite and genthite. Mode of occurrence of native silver.

Order of generation of component minerals.

Vein No. 1 lies east of the railway track, at the edge of a swamp, about a quarter of a mile north of the end of Long lake. It has been uncovered at three points, which are within a few yards of one another. Medium-grained, dark-coloured conglomerate, is found on one wall. At the widest opening, the deposit has a width of over 6 feet, but the vein matter is more or less mixed with rock. The ore consists of niccolite or the arsenide of nickel, and smaltite, the diarsenide of cobalt, together with much native silver. On weathered surfaces, the vein matter is coated with the beautiful decomposition product, erythrite (cobalt bloom). The green nickel stain (annabergite?) is also seen on some surfaces, but is usually masked by that of the cobalt. Nickel silicate (genthite) may also be present. The secondary mineral arsenolite (As_2O_3) also occurs. Native silver, in leaves, films and fine threads, and moss-like forms, is intimately associated with the nickel and cobalt minerals especially with the niccolite, as well as in cracks in the rock and in the calcite veinstone. In weathered portions of the ores, the silver shows distinctly. One sheet, composed chiefly of silver, had a thickness of nearly 0.375 of an in. and a diameter of about one foot. The silver appears to have crystallized earlier than the niccolite, which has been deposited around it. The smaltite has formed still later than the niccolite.

Vein No. 1 made up of smaltite and niccolite.

On location No. 2, which lies about half a mile southwest of No. 1, the ore body is distinctly vein-like in form. The ore is a mixture of smaltite, and probably some closely related arsenide, such as safflorite ($CoAs_2$), and niccolite. It was found to have the following composition :

Composition of ore.

	I.	II.	III.	IV.
Cobalt	16·8	16·76	19·80	21·70
Nickel	7·0	6·24	4·56	
Iron	6·3	.....	6·20	8·89
Arsenic	69·0	66·60	60·30	63·55
Sulphur		3·57	4·09	5·38
Insoluble	0·9	.....	2·40	0·60
Water	.....	....	2·00	.....

Analysis I. was made by O. S. James; II. and III. are of average samples collected by W. G. Miller, the former from the uppermost opening, the latter from the middle or main opening the analyst being A. G. Burrows. It was evident that III. was somewhat weathored, as it showed considerable cobalt bloom. Analysis IV. is by Dr. J. Waddell. It represents a specimen collected by Prof. Nicol This specimen was not taken like II. and III., with the object of determining the average composition of the vein. Prof. Nicol states that a qualitative analysis showed the presence of small amounts of copper and lead, and the absence of antimony, bismuth and zinc.

This ore body, unlike the others examined, carries no silver, in the parts so far discovered. Three openings have been made in the vein, over a length of 300 feet. The massive ore has a width of 14 inches, but vugs in the wall rock, 2 feet or more from the vein, are filled with cobalt bloom. The walls, which are well defined, are of slate, and the vein is almost perpendicular, lying on the hillside, about 70 feet above the level of Long lake, and a few hundred yards east.

Mode of occurrence of vein No. 2.

Ore body No. 3, lies at the southern edge of Long lake, about half a mile southwest of No. 2. It is very similar to No. 1, consisting of native silver, smaltite, erythrite, and, in all probability, niccolite.

Character of No. 3 vein.

Vein No. 4, is about half a mile southeast of No. 3. The vein, averaging not more than 8 inches, cuts a perpendicular bare cliff, facing the west, nearly 70 feet high. The vein is weathered away, leaving a crack in the face of the cliff, in some places, 4 or 5 feet in depth. Thin leaves of silver, up to 2 inches in diameter, were lying on the ledges, and the decomposed matter was cemented together by the metal. It was found impossible to get a fresh sample of the ore, with the hammer, the vein being so much decomposed. The weathered specimens, however, in addition to the native silver, contained erythrite, and the unaltered ore will be found in all probability to consist of smaltite and niccolite, in addition to the silver. Across a distance of 8 inches, a distinct banded structure was noticed, and there were 12 or 14 layers of ore, lying parallel to the walls. A sample of the much weathered ore from vein No. 4, which appeared to contain less silver than most of the samples collected, was found by Mr. A. G. Burrows to have the following percentage composition: Silver 16·60, cobalt 3·91, nickel 1·42, arsenic 16·79, gold none. This ore is brownish to yellowish in colour, and has an earthy appearance. Its colour is due to the presence of several decomposition products, the oxides of iron, cobalt and nickel. A small amount of cobalt bloom is present. At the bottom of the cliff, the vein cuts thin banded, dark grey or greenish, at times, almost

Mode of occurrence and character of vein No. 4.

Ore body made up of smaltite, niccolite with native silver.

Composition of ore bodies.

black slate, which has a slight dip. The slate passes gradually, as far as could be discovered, from the steep character of the cliff, into a coarse breccia-conglomerate, in the upper part. The fragments in the conglomerate, consist of quartz, slate, granite and other rocks.

Occurrence of heterogenite and asbolite.

On some of the native silver specimens, there are small, black, speroidal masses, with little lustre. These appear to be the hydrated oxide of cobalt (heterogenite). Some of the deposits, on the silver, resemble asbolite. The carbonates of cobalt and nickel are also probably present.

Recognition of dyscrasite and chloanthite by Prof. Nicol.

Prof Nicol, of the Kingston School of Mines, who afterwards examined the material collected, recognized the silver antimonide, dyscrasite, in association with the native silver of No. 1. He has also definitely determined the presence of chloanthite, (arsenide of nickel). It is associated with the niccolite, and also occurs rather free from cobalt, in some of the nodular masses.

Occurrence of smaltite and erythrite west of Rabbit lake.

Smaltite and erythrite, have also been met with in small quantities, associated with the basic igneous rocks, to the west of Rabbit lake, so that the whole area, where such rocks occur in the Timiskaming and Temagami districts, should be carefully prospected. Although the width and extent of these veins, may not be very great, the character of the ore is such as to make them a distant economic possibility, at the present ruling prices of the metals contained in them.

OTHER ASSAYS FOR NICKEL OF THE SULPHIDE ORES IN CANADA.

Active prospecting for nickel after discovery of Sudbury deposits.

Numerous assays made by Geological Survey Dept.

Since the discoveries of the highly nickeliferous pyrrhotite of the Sudbury Mining District, there has been very active prospecting for similar sulphide material. Numerous specimens, from all parts of the Dominion, have come to the laboratory of the Geological Survey Department, for assay. The material, thus submitted, has been examined, and partial analyses have appeared, from time to time, in the reports of the Section of Chemistry and Mineralogy, which, besides, appearing as separates, are included in the various annual volumes. It has been thought advisable to tabulate these results, arranging them according to provinces. All of the analyses have been conducted by Messrs. R. A. Johnston and F. G. Wait, assistants to Dr. G. C. Hoffmann, the chemist and mineralogist to the Geological Survey. These analyses are in addition to those which have been already quoted, on previous pages of this bulletin.

Analyses performed by Messrs R. A. A. Johnston and F. G. Wait.

PARTIAL ANALYSES OF NICKEL ORES IN CANADA.

Partial analyses of nickel ores from Ontario.

ONTARIO.

No.	Locality.	Gangue.	Cu.	Ni.	Co.	Ni. in metallic portion.	Analyst.
1	Clarendon, Frontenac Co	60·00	....	Trace.	0·20	....	R. A. A. Johnston.
2	Lot 10, con. IV., Creighton, Algoma	16·00	....	None.	None.	......	R. A. A. Johnston.
3	Schreiber, (2 miles west of) Thunder Bay Dist	None.	....	0·03	Trace.	......	R. A. A. Johnston.
4	Same locality	10·00	....	Trace.	Trace.	.....	R. A. A. Johnston.
5	Darlington Bay, L. of the Woods	20·00	....	〃	〃	.....	R. A. A. Johnston.
6	E. ½ lot 18, con. III., Dalhousie, Lanark Co	20·50	....	0·09	〃	0·11	F. G. Wait.
7	Lot 15, con. A. Anglesea, Addington Co	37·89	Present.	0·10	〃	0·16	F. G. Wait.
8	Lot 12, con. III., Galway, Peterborough Co	....	....	0·16	〃	.....	F. G. Wait.
9	Lot 18, con. IV., Galway, Peterborough Co	17·25	....	0·10	〃	0·12	R. A. A. Johnston.
10	Lot 16, con. XIV., Galway, Peterborough Co	....	Present.	0·10	〃	......	F. G. Wait.
11	S. end lot 16, con. XIV., Galway, Peterborough Co	....	〃	0·05	〃	....	R. A. A. Johnston.
12	Lot 16, con. XV., Galway, Peterborough Co	38·46	....	faint traces	......	.....	R. A. A. Johnston.
13	Galway, Peterborough Co	....	....	0·04	Trace.	......	F. G. Wait.
14	Lot 1, con. XI, Somerville, Victoria Co	62·36	....	fai. tr.	.....	.....	R. A. A. Johnston.
15	Somerville, Victoria Co	48·97	....	0·06	Trace.	0·12	F. G. Wait.
16	N. part of Victoria Co	....	....	0·15	〃	......	F. G. Wait.
17	S. E. shore Vermilion lake, Nipissing Dist	....	......	0·05	Pres't.	.....	F. G. Wait.
18	Lot 6, con. I., Hyman, Algoma Dist	....	....	......	None.	1·55	R. A. A. Johnston.
19	English River, 9 miles N. of C. P. Ry., District of Rainy River	10·50	....	0·12	None.	0·13	F. G. Wait.
20	Near Jackfish station, C. P. Ry., Thunder Bay Dist	....	....	Trace.	....	....	F. G. Wait.
21	Twelve Mile lake, Minden, Haliburton Co	6·92	....	0·13	Trace.	0·14	F. G. Wait.

No.	Locality.	Gangue.	Cu.	Ni.	Co.	Ni. in metallic portion.	Analyst.
22	Lots 32 and 33, con. XI., Sebastopol, Renfrew Co.......	....	Present.	......	None.	0·10	F. G. Wait.
23	E. ½ lot 18, con. III., Dalhousie, Lanark Co..............	29·35	... .	0·165	Trace.	0·23	F. G. Wait.
24	Matawatchan, Renfrew Co....	....	....	......	〃	0·29	F. G. Wait.
25	Cutting on Whitney and Opeongo Ry., 7½ miles from junction with C. A. Ry., Sproule, Nipissing District.......... .	....	Present.	0·19	〃	......	F. G. Wait.
26	Lot 17, con. II, Westmeath, Renfrew Co	....	〃	fai. tr.	None.	....	R. A. A. Johnston.
27	N. ½ lot 4, con. IV., Graham, Algoma District.........	1·04	....	0·49	Trace.	0·49	F. G. Wait.
28	S. ½ lot 8, con. IV., Dowling, Algoma District...........	....	Present.	.. .	〃	0·26	F. G. Wait.
29	W. ½ lot 10, con. IV., Olden, Frontenac Co.......	3·32	〃	0·98	〃	1·02	F. G. Wait.

EXPLANATIONS.

Explanation and description of specimens analyzed from the Province of Ontario.

1. A grayish-white, gneissoid rock, through which was disseminated a somewhat large amount of pyrrhotite. The metallic portion of the ore contained, 0·5% of cobalt. 2. Coarse, granular pyrrhotite, in association with zinc blende, through which was disseminated a somewhat small amount of a dark gray, schistose rock and white quartz. 3. Pyrrhotite, from an extensive deposit. Examined for Mr. Thomas Marks. 4. A fair sample of the pyrrhotite, from the same locality. Collected by Dr. Selwyn. A fine, granular, massive pyrrhotite, through which was disseminated a little quartzose gangue. 5. Pyrrhotite, with a dark gray gneissoid rock. Examined for Mr. Mather. 6. Pyrrhotite, with a little pyrite, in quartz mica-diorite. Examined for Mr. W. C. Caldwell. 7. A dark gray gneissoid rock, through which was disseminated a fairly large amount of pyrrhotite, and a trifling quantity of chalcopyrite, 8. A compact, massive pyrrhotite. Examined for Mr. E. D. Orde. 9. A massive pyrrhotite, in association with very small quantities of pyrite in quartz. Collected by Dr. F. D. Adams. 10. A compact, massive pyrrhotite, with a little pyrite, and trifling amounts of chalcopyrite and quartz. Examined for Mr. R. H. G. Chapman. 11. Massive pyrrhotite, with very small quantities of chalcopyrite, quartz and felspar. Collected by Dr. F. D. Adams. 12. Quartz ,carrying some pyrrhotite, and a small quantity of pyrite. 13. Lot and concession not

Brief descriptions of specimens examined from Province of Ontario.

communicated. Massive pyrrhotite, with a very trifling amount of calcite. 14. Quartz, a little felspar, and a very little garnet, carrying a small quantity of pyrite and pyrrhotite. Collected by Dr. F. D. Adams. 15. Pyrrhotite, with quartz, and a little garnet. Number of lot and concession not communicated. 16. A compact, massive pyrrhotite. 17. From E. V. Wright's claim, north of Northeast Arm of Lake Temagami. A very fine, crystalline, massive pyrite, in a gangue of quartz-diorite. Collected by Mr. A. E. Barlow. 18. Pyrrhotite, with mica and but little visible quartz. Collected by Mr. W. McInnes. 20. A very fine, granular pyrite with small quantities of pyrrhotite. 21. Compact massive pyrrhotite, with a little pyrite, and a small quantity of quartz. 22. Compact, massive pyrrhotite, with small quantities of chalcopyrite and pyrite, in a gangue of calcite, pyroxene, some hornblende, felspar and a little garnet. Examined for Mr. L. Meany. 23. Quartz, with a little hornblende, carrying large quantities of pyrite and pyrrhotite. Examined for Mr. T. B. Caldwell. 24. Compact, massive pyrrhotite, with a small quantity of quartz and hornblende-gneiss. 25. Compact, massive pyrrhotite, with a few particles of chalcopyrite, and a small quantity of gangue, mainly quartz and felspar, with a very little garnet. Examined for Mr. A. H. N. Bruce. 26. Pyrrhotite, with a little chalcopyrite, apatite and hornblende. 27. Massive pyrite, associated with pyrrhotite, chalcopyrite and danaite, (cobaltiferous arsenopyrite). 28. A massive pyrrhotite, with which was associated a little chalcopyrite and a somewhat large proportion of gangue (vitrophyre-tuff). 29. Granular, massive pyrrhotite, with a very little chalcopyrite, with a little gangue of felspar, quartz and hornblende. Examined for Mr. J. Bawden.

QUEBEC.

Results of partial analyses of sulphides from the Province of Quebec.

No.	Locality.	Gangue.	Cu.	Ni.	Co.	Ni. in metallic portion.	Analyst.
30	Lake Mistassini.....	27·00	....	Dist. traces	Dist. traces	......	R. A. A. Johnston.
31	Lot 24, R. 18, Potton, Brome Co........	Small amount	....	Small amt.	... ..	.....	R. A. A. Johnston.
32	Lot 24, R. 7, Clarendon, Pontiac Co...	None	....	1·50	Trace.	1·50	R. A. A. Johnston.
33	Lot 2, R. 8, Eardley, Ottawa Co........	....	....	0·13	None.	.... .	R. A. A. Johnston.
34	Lot 14, R. 6, Aylwin, Ottawa Co........	....	.. ..	......	"	1·68	F. G. Wait.
35	Lot 14, R. 5, Masham, Ottawa Co...	....	Present.	A litt.	.....	Co. Ni 0·28	F. G. Wait.
36	Lot 14, R. 5, Masham, Ottawa Co....	....	......	0·11	None.	.....	F. G. Wait.
37	Same locality.	....	....	0·10	"	.....	F. G. Wait.

Description of geological association of specimens selected for analysis from Province of Quebec.

EXPLANATIONS.

30. Pyrrhotite, in gangue of hornblende schist. Collected by Mr. Walter McOuat (Survey) in 1872. 31. Pyrrhotite, chalcopyrite and pyrite, with small amount of gangue. One specimen contained a very small amount, and the other, a trace of nickel. 32. Pyrrhotite, but the material does not, so far as is known, occur in quantity. 33. A massive pyrrhotite. Examined for Mr. W. A. Allan. 34. Pyrrhotite, almost pure, or with quartz, felspar, mica, hornblende and calcite. 35. Massive pyrite, with a few particles of chalcopyrite, and a somewhat larger proportion of granite. 36. Massive pyrrhotite, with a very little quartz. 37. Taken from a different part of the deposit. Pyrrhotite, a little pyrite and a very small amount of gangue of black garnet and pyroxene, and a very little quartz. Nos. 36 and 37, were examined for Mr. W. L. Marler.

BRITISH COLUMBIA.

No.	Locality.	Gangue.	Cu.	Ni.	Co.	Ni. in metallic portion.	Analyst.
38	Near head of Barclay sound, Vancouver I	....	....	Trace.	Trace.	......	R. A. A. Johnston.
39.	Monashee mine, near head of Cherry creek..........	....	Present.	None.	Trifl'g Am't.	.....	R. A. A. Johnston.
40	Illecillewaet dist....	16·75	Present.	0·12	Trace.	0·14	F. G. Wait.
41	Creek flowing into Downie creek, 20 miles above fork with Columbia R., West Kootenay district...........	....	....	Faint traces	.....	.....	R. A. A. Johnston.
42	Crawford bay, Kootenay lake.	....	Present.	Trace.	.....	......	F. G. Wait.
43	Same locality......	10·70	Present.	0·048	None.	0·053	F. G. Wait.
44	A few miles N. of Savona station, C. P. R., Yale dist...	10·17	Present.	0·031	....	0·034	F. G. Wait.
45	Between N. Thompson and Clearwater rivers.	....	Present.	Trace.	......	.....	F. G. Wait.
46	Mission City claims, townships 17 and 18, Westminster dist.	36·50	Present.	0·055	Trace.	0·09	F. G. Wait.
47	Jarvis inlet.........	14·80	Present.	0·24	Trace.	0·28	F. G. Wait.
48	King Solomon mine, Kaslo-Slocan mining camp, West Kootenay dist.....	0·36	....	0·15	Trace.	.....	F. G. Wait.
49	E. side, Upper Arrow lake, about 12 miles from its head, W. Kootenay dist.....	....	Present.	......	None.	0·12	F. G. Wait.

BRITISH COLUMBIA.—*Cont.*

Results of assays for nickel and cobalt of sulphides from the Province of British Columbia.

No.	Locality.	Gangue.	Cn.	Ni.	Co.	Ni. in metallic portion.	Analyst.
50	Monte Cristo claim, Trail creek, Columbia river	....	Present.	......	Strong trace.	0·13	F. G. Wait.
51	Iron Colt claim, Trail Creek, Columbia river	14·50	Present.	0·20	Strong trace.	0·234	F. G. Wait.
52	Bunbury claim, near Lac le Bois, Interior Plateau Region	17·83	....	0·065	Trace.	0·08	F. G. Wait.
53	Humphrey claim, Lac le Bois. Interior Plateau Region............ ...	59·20	....	0·04	Trace.	0·10	F. G. Wait.
54	Quartz creek (Salmon R.), 20 miles south of Nelson...	......	......	....	......	Trace.	F. G. Wait.
55	Kootenay-Columbia property, 1¼ miles N.E. of Rossland.	29·03	Present.	0·65	Trace.	0·92	F. G. Wait.
56	Queen Victoria claim, 8 miles W. of Nelson.........	37·15	Present.	0·43	Trace.	0·68	F. G. Wait.
57	Evening Star mine, E. slope Mt. Monte Cristo, 1 mile N. of Rossland.	62·73	Present.	0 25	0·59	Ni.0·67 Co.1·58	F. G. Wait.
58	Leviathan Group of claims, Campbell creek, E. side of Kootenay lake.. ..	61·84	Present.	0·06	None.	0·16	F. G. Wait.
59	R. & K. claim, 1 mile N. of Argenta, W. Kootenay dist......	....	Present.	0·05	"	......	F. G. Wait.
60	Kennedy lake, W. coast, Vancouver island	7·50	"	0·15	Trace.	0·16	F. G. Wait.
61	Two Sisters and Crow Claim, Deer creek, Clayoquot, Vancouver island.. ...	41·00	Present.	0·69	Trace.	1·70	F. G. Wait.
62	N.E. ¼ Section, Block I., W. side of Texada island..	....	....	Faint trace.	......	......	R. A. A. Johnston.
63	Near Kruquot, W. coast Vancouver island...... ...	....	Present.	Trace.	...	. ..	F. G. Wait.
64	Mt, W. of Ice river, 6 miles from forks with Beaverfoot R., East Kootenay district...........	0·20	....	0·12	None.	0·12	F. G. Wait.
65	N. bank of the Thompson, about 5 miles above Lytton, Yale district.	17·72	Present.	0·08	Trace.	0·097	F. G. Wait.
66	Shuswap lake.......	15·75	Present.	Trace.	None.	.... .	F. G. Wait.

EXPLANATIONS.

Explanation and description of sulphides assayed for nickel and cobalt from the Province of British Columbia.

38. A massive pyrrhotite. Examined for Capt. J. Jaques. 39. An association of white translucent quartz and dark green diorite, carrying large quantities of pyrrhotite, and a little chalcopyrite. 40. Pyrrhotite, with a little chalcopyrite, and a small quantity of a dark green rock. 41. Quartzo-felspathic rock, with a large amount of pyrrhotite. Examined for Mr. J. D. Boyd. 42. Pyrrhotite, with a very small amount of chalcopyrite, in quartz. 43. Pyrrhotite, with small quantities of chalcopyrite and graphite, quartz, felspar and mica. These two last were examined for Cockle Bros. 44. Massive pyrrhotite, with a few specks of chalcopyrite, and a small quantity of quartz. Examined for Mr. J. Dickenson. 45. Pyrrhotite, with small quantities of chalcopyrite. 46. Fine, granular pyrrhotite, with small quantities of pyrite and chalcopyrite, and a somewhat large proportion of gangue. Examined for Mr. D. Elliott. 47. Pyrrhotite, with some chalcopyrite, and a little galena, with a small proportion of gangue, composed of quartz and fine-grained diorite. 48. Compact, massive pyrrhotite, through which was disseminated very small quantities of quartz. Examined for Mr. H. E. Porter. 49. Quartz, with a little chlorite and mica, carrying small quantities of a compact massive pyrrhotite, a little pyrite and a few specks of chalcopyrite. Examined for Mr. R. Sanderson. 50. Pyrrhotite, with a little chalcopyrite, and small quantities of a quartzose gangue. 51. Exceedingly fine-grained pyrrhotite, with a little chalcopyrite, and small quantities of a quartzose gangue. 52. A felspathic rock, carrying small quantities of pyrrhotite. 53. Quartzo-felspathic rock, carrying small quantities of pyrrhotite. 54. Pyrrhotite and pyrite, with small quantities of calcite and felspar. 55. Pyrrhotite and chalcopyrite, with a little gersdorffite, in a somewhat calcareous gangue. 56. Pyrite and chalcopyrite, with some pyrrhotite, in a gangue of andradite, quartz, and a few scales of mica. 57. Arsenopyrite and chalcopyrite, in a gangue of hornblende and calcite. Danaite or cobaltiferous arsenopyrite, carrying 3.05 per cent cobalt, also occurs at this mine (Ann. Rep. Geol. Surv. Can., Vol. VIII, 1895, Part R p. 13). 58. Quartz, with a little felspar, hornblende and graphite, with a small quantity of pyrrhotite, and a very little chalcopyrite. Examined for Mr. F. W. Pettit. 59. Massive pyrrhotite, with a very little chalcopyrite, and a trifling amount of quartz and felspar. Examined for Mr. J. Turner. 60. Massive pyrrhotite, with a few particles of chalcopyrite, and a small quantity of gangue, made up mainly of garnet and calcite, with a little quartz and hornblende. 61. Chalcopyrite, with some pyrrhotite, and a small quantity of quartz.

Examined for Mr. F. Jacobsen. 62. Very fine, granular, massive pyrrhotite. Examined for Mr. Alfred Raper. 63. Granular, massive pyrrhotite, with a very little chalcopyrite. Examined for Mr. G. H. Franklin. 64. Compact, massive pyrrhotite, with a little quartz. Examined for Mr. James Walker. 65. Fine, granular, massive pyrrhotite, with some pyrite, and very little chalcopyrite, with a gangue mainly of hornblende and quartz. Examined for Mr. Geo. de Wolf. 66. Compact, massive pyrrhotite, with a little chalcopyrite, and a somewhat large quantity of quartz. Examined for Mr. J. T. Edwards.

NEW BRUNSWICK.

Assay, for nickel and cobalt, of pyrrhotite from New Brunswick.

No.	Locality.	Gangue.	Cu.	Ni.	Co.	Ni. in metallic portion.	Analyst.
67.	L'Etete, Charlotte Co	....	present.	present.		......	R. A. A. Johnston.

EXPLANATION.

Description of association.

67. Pyrrhotite, like that from St. Stephen, with a little chalcopyrite in a gangue of diorite.

NOVA SCOTIA.

Determinations of nickel and copper, of sulphides from Nova Scotia.

No.	Locality.	Gangue.	Cu.	Ni.	Co.	Ni. in metallic portion.	Analyst.
68.	Barrachois harbour, Cape Breton Co...	....	....	trace..	none .	trace..	R. A. A. Johnston.
69.	Lutche creek, Cape Breton Co...	25·40	....	0·75	trace..	1·00	F. G. Wait.
70.	Boularderie Centre, Victoria Co.......	12·41	present.	0·07	trace..	0·08	F. G. Wait.

EXPLANATIONS.

Description of geological association.

68 Pyrrhotite. Examined for Mr. Alex. McLeod. 69. Pyrrhotite, with a somewhat large amount of silicious gangue, from the land of Mrs. O'Hanley, on the rear of George river. Examined for Mr. Alex. McLeod. 70. Massive pyrrhotite, with a few particles of chalcopyrite, and a little hornblende and quartz. Examined for Mr. William Haggerty.

MISCELLANEOUS.

Assays, for nickel and cobalt, of pyrrhotite from North-west Territories and Ungava District.

No.	Locality.	Gangue.	Cu.	Ni.	Co.	Ni. in metallic portion.	Analyst.
71	Deer river, (tributary of Churchill R., N.W.T.).............	42·20	....	0·06	Trace.	0·10	F. G. Wait.
72	Island, off W. point of Kogaluk R., East coast, Hudson bay, Ungava district..	48·00	....	0·08	Present.	0·15	R. A. A. Johnston.

EXPLANATIONS.

71. Pyrrhotite in a gangue of quartz, felspar, and a little mica and graphite. Collected by Mr. D. B. Dowling. 72. Massive pyrrhotite, with a large amount of quartz.

Description of geological association.

THE NICKEL DEPOSITS OF SCANDINAVIA.

Nickel deposits of Norway very closely analogous to those of Sudbury.

The nickel deposits of Norway and Sweden are of especial interest to us, since they resemble, in all essential particulars, the larger and richer deposits of the Sudbury District. It would be impossible, within the scope of the present bulletin, to give a full, or even satisfactory account of these occurrences, and the various phenomena attendant on their geological associations, and the reader is referred for such details, to the elaborate and epoch-making work of Prof. J. H. L. Vogt, of Christiania, Norway. (1)

Work by Prof. J. H. L. Vogt.

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(1) Vogt, J. H. L., 'Nikkel forekomster og Nikkelproduktion.' Geol. Soc. Norway, Christiania. 1892. 'Sulphidische Ausscheidungen von Nickelsulphiderzen.' Zeit. für. Prak. Geol., 1893, also 1894, 1895, 1900 and 1901. 'Ueber die Bildung von Erzlagerstätten durch Differentiationprocesse in Eruptivmagmaten.' International Geol. Congress, Zurich, 1894. 'The Formation of Eruptive Ore Deposits.' Min. Ind. Vol. IV, 1895. 'Problems in the Geology of Ore Deposits.' Trans. Am. Inst. Min Eng. Richmond, 1901. 'Platingehalt in norwegischen Nickelerz.' Zeit. für Prak. Geol., Aug. 1902.

All of the Scandinavian nickel deposits are intimately related to masses of gabbro or norite. In Norway, there are about 40 of these masses, with which deposits of nickeliferous pyrrhotite are associated, these being the largest nickel deposits in Europe.

All Scandinavian deposits associated with gabbro or norite.

These masses, which are undoubtedly of igneous origin, are either composed of gabbro, which is essentially an admixture of plagioclase felspar and augite, or of norite, a closely related rock, made up principally of plagioclase felspar and hypersthene (rhombic pyroxene). These masses of gabbroic material, occur in the Archæan hornblende schists and gneisses, generally intruded parallel to their foliation or lamination but often cutting across them. The norite of all these masses, shows a remarkable tendency to differentiation, so that the same mass, in different parts of its extent, will vary greatly in the relative proportions of the constituent minerals. The principal types of such differentiates, are often distinguished as gabbro, olivine gabbro, and pyrrhotite gabbro and norite, olivine norite and pyrrhotite norite, while the decomposed representative is distinguished as uralite-gabbro.

Mineralogical composition of norite.

Norite intrusive in Archæan schists and gneisses.

Differentiation of norite.

The ore is chiefly pyrrhotite, containing, when pure, from 2·5 to 5 per cent of nickel and cobalt, but as much as 7 per cent is sometimes found. These metals are usually present in the proportion of one part of cobalt, to from seven to twelve parts of nickel. Associated with the pyrrhotite (Fe_8S_9) are pyrite (FeS_2), chalcopyrite ($CuFeS_2$), and, in some places, ilmenite or titaniferous magnetite. Chalcopyrite is never present in large amount. The pyrite usually contains more cobalt than nickel. In the nickel ore, in a few places, the mineral pentlandite (eisennickelkies), is distinctly discernible, and, in a single case, the mineral cobaltite.

Average percentage of nickel and cobalt in Scandinavian pyrrhotite.

General character of ore.

Occurrence of pentlandite.

The pyrrhotite, chalcopyrite and pyrite, are regular constituents of the gabbro or norite, occurring in small quantities, all through the various masses, but, like the other constituents of the rock, are found more abundantly in certain places, and a gradual transitition can often be observed, from the normal gabbro to pyrrhotite-gabbro, and to masses of pure pyrrhotite, with little or no rocky or silicate admixture. Occasionally, the ore occurs in masses, sharply separated from the norite, as at the Ertelien mine. These segregations of ore, are, in the great majority of cases, situated either directly at, or near the edge of the igneous masses, and Vogt regards these concentrations as distinctly comparable to the basic borders or edges, so often observed, about granites and other igneous rocks, in which the basic borders are sometimes marked by similar gradual passages, and, in some cases, by rather abrupt transitions.

Sulphides are regular constituents of norite.

Ore bodies situated near edge of norite mass.

Ore bodies regarded by Vogt as analogous to ordinary basic edges of igneous masses.

Ratio of copper and nickel in Scandinavian, Italian and Canadian occurrences.

Prof. Vogt draws attention to the fact, that the average proportion of nickel to copper in the Norwegian ores is about 100 to 40 or 50 and that in the Varallo (Piedmont, Italy) occurrence about the same proportion holds good, while in Canada, where the associated igneous rocks are more acid in composition, there is sometimes relatively more copper, 100 parts nickel to 100 or 150 parts of copper being found in some of the deposits.

Ratio of Nickel to Copper in some of the most important of the Scandinavian mines.

Name of Mine.	Content of Copper corresponding to 100 parts of nickel.	Percentages of nickel and cobalt in the pure pyrrhotite.
Grägalten mine......	75–80	about 2·50
Klefva mine..........	55	about 2·75–3·00
Ertelien mine	45–50	about 3·00
Bamle district. . .	35–40	about 3·50–4·00
Flaad mine.....	37	about 4·50
Senjen mine.........	35–40 (about)	about 3·50–4·00
Dyrhaug mine.......	30–35	about 3·80–4·20
Beiern mine..	20–25 (about)	about 7·00

Amount of gold, silver, platinum, iridium and osmium in Scandinavian mattes.

The Scandinavian ores also contain small quantities of silver, gold, and metals of the platinum group, including platinum, iridium and osmium. The amount of these metals is shown by the following analyses of the matte, from the Ringerike and Evje nickel smelters. (1)

Analyses of mattes from Ringerike and Evje nickel smelters.

—.	Ringerike %	Evje %
Nickel.........	51·16	41·50
Cobalt.........	1·98	0·97
Copper.	16·41	23·60
Iron.........	10·87	(13)
Sulphur.......	19·58	(20)
	g. per t.	g. per t.
Silver..........	85	140
Gold....	0·5	1 (about)
Platinum......	2·6	3 (about)
Iridium.. ...	0·1 (about)	....
Osmium.		....

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(1) Zeit. für Prak. Geol., Aug., 1902, p. 259.

The mineral associations of the precious metals, is shown by the following table (¹) of analyses of the ore from the Flaad mine at Evje.

Analyses of Norwegian ore showing mineralogical associations of the precious metals.

—	Ni & Co.	Cu.	Insoluble.	Ag.	Au.	Pt.
	%	%	%			
Pyrrhotite (mainly).	4·37	0·35	9·02	4	Trace.	......
	·50	0·60	16·00	Trace.	0	......
	2·90	0·21	20·63	6	......	......
	3·31	0·67	17·46	Trace.	0	......
Chalcopyrite and pyrrhotite...	2·60	8·00	18·90	44	Trace.	......
	1·70	13·33	14·40	48	"	Trace.
Chalcopyrite.........	....	....	....	37	......	......
				80	......	Trace.

History of nickel mining in Sweden and Norway.

Discovery of nickel in Scandinavian ores.

Erection of nickel smelters.

Reasons for establishment of Scandinavian nickel industry.

Mining for nickel began in Sweden between 1838 and 1840, at Klefva (Smaland), and in Norway, between 1847-50 at Espedal and Ringerike. In 1838, Berzelius showed that the pyrrhotite from the Klefva mine, in Smaland, in southern Sweden, contained nickel. Before that time, this mine had been worked for copper. When the fact was announced that the ore contained about 3 per cent nickel, it was decided to erect a smelting plant for nickel, this being the oldest nickel smelting plant in Scandinavia. In the beginning of 1840, Th. Scheerer, the professor of metallurgy in the University of Christiania (who had been born in Saxony, and was manager of the Modums works), described the new mineral eisennickelkies (with 22 per cent of nickel), from Espedalen (Gausdal). Scheerer also announced that nearly all the Norwegian pyrrhotite and pyrite contained nickel and cobalt. The publication of these results, was really the cause of the erection of the nickel plant at Espedalen, which was in operation, on a large scale, between 1840 and 1850, with a staff of 200 men. This smelter, however, was closed down about 1855. In 1837, Scheerer analyzed the pyrrhotite from Modums, and found it to contain 2·80 per cent of nickel. This pyrrhotite had been obtained from the Ertelien mine, which, later on, proved to be the chief mine supplying the Ringerike nickel smelter. About 1700, these works had been used for copper, and had, in the first half of the last century, a small plant for the production of vitriol and red paint. Scheerer supplied information to his friend, A. Roscher, (who is described as being descended from a mining engineer), as to where

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(1) Zeit. für Prak. Geol., Aug., 1902, p. 258.

he had found the pyrrhotite. This man had also been working in connection with the paint plant at Modums and Snarums. All of these facts combined, helped to bring about the establishment of the nickel industry in Scandinavia.

Kragero nickel smelter.

Between 1850 and 1860, and towards the latter end of this decade, the nickel mines in connection with the Kragero nickel smelter, were started by D. Forbes and the two brothers J. and T. Dahll. During the nickel boom about 1870, there were several nickel refineries located in Norway, while, at the same time, the plants of Sweden, Austria Hungary, and Italy, supplied a large quantity of nickel, but Norway, during this period, was the largest producer of nickel in the world. After the discovery of the nickel in New Caledonia, and its advent on the market, between 1876 and 1878, the price of nickel fell to such a degree, that most of the European nickel smelters closed down, or decreased their production, and from 1877-80, up to 1888-89, New Caledonia produced from two thirds to three fourths of all the nickel in the market. Quite recently, the production of nickel from New Caledonia, has, in turn, been exceeded by that of Canada.

Many refineries erected in 1870.

Curtailment of operations owing to abundance of New Caledonia ores.

Supremacy of Canadian ores.

From 1848 to 1892, about 330,000 metric tons of nickel ore were mined in Norway. The maximum yearly output was in 1876, when 42,500 tons were mined. From that time, till 1892, from 5,000 to 7,000 tons per annum, were produced. The average nickel contents of the ore per annum have been as follows; 1851-1860, 20 tons; 1861-1872, 45 tons; 1873-1876, 245 tons; 1876, 360 tons; 1877-1880, 100 tons; 1881-1885, 125 tons; 1886-1892, 105 tons.

Production of metallic nickel in Norway.

Since 1892, the production of Norwegian nickel ore and nickel, have been as follows.

Table of production of ore and nickel in Norway from 1893 to 1900.

	Nickel Ore metric tons.	Value. $	Metallic Nickel. metric tons.	Value. $
1893	2397	6,480	113	70,605
1894	2355	5,400	103	63,450
1895	494	1,080	17	10,530
1896	315	.....	16	8,100
1897	nil	.....	nil	.....
1898	nil	.....	nil	.....
1899	220	810	5	2,700
1900	1888	12,690	13	9,720

Production of nickel from Norwegian ores in 1901.

In 1901, the *Mineral Industry* states that 27 tons of nickel were produced from Norwegian ores, but this is included in the United States production from imported ores.

Rich nickel ore at Beiern.

In some of the mines, small bodies of rich ore have been found, as for example, at Beiern, where ore was encountered with an average of 7 per cent nickel (nickel-bearing pyrite and pyrrhotite); and, in other places with an average of about 5·5 per cent. In the better mines, first class smelting ore can often be sorted out, but the grade of the bulk of the ore is much lower. In 1870, miners were satisfied with a yield of 0·8 to 1·3 per cent of nickel from the smelting ore, the actual assays of which were from 0·9 to 1·5 per cent. In later years, when only the richer mines have been operated, and hand sorting has been practiced, with more care, the yield has increased from 1·4 to 1·5 per cent, almost to 2·5 per cent, with an average of 2 per cent. In the mines, the cost of producing one ton of ore, assaying about 2 per cent nickel, varies from $1.67 to $3.09, averaging $2.38. (1)

Average percentage of nickel in Norwegian ores.

Cost of mining.

Production of nickel ore and metallic nickel in Sweden.

From 1861 to 1891, Sweden produced nearly 80,000 tons of ore. From 1866 to 1875 the nickel contained in the Swedish ores averaged from 65 to 70 tons per annum; 1876-80, 50 tons; 1881-85, 30-40 tons. Since 1886, however, the nickel contained in these ores, has only averaged from 10 to 15 tons per annum. The last year in which there was any production of Swedish nickel ore was in 1891, when 483 tons were mined. None of the Norwegian mines are at present in operation, although attempts are being made to revive the nickel industry in that country. The keen rivalry of Canada and New Caledonia will, however, prevent any extensive operations, at least, for many years to come.

No Norwegian mines at present working owing to abundance of material from Canada and New Caledonia.

NICKEL IN EUROPE.

Nickel first produced at Schneeburg.

Nickel was first produced at Schneeburg, on the suggestion of Dr. Geitner, who erected a plant for the manufacture of the alloy known as 'new silver'. They used, as their raw material, the dumps from the cobalt works. These dumps were soon exhausted, and it became necessary to prospect for nickel ore. Early in the last century, several small nickel deposits were discovered, in Germany and Austria-Hungary, as for instance, at Dillenburg, in Nassau, which was provided with a smelting plant in 1843, Dobschau, in Hungary, etc.

Discovery of deposits in Germany and Austria-Hungary.

Deposit of nickel at Varallo, Italy.

The nickel deposits of Varallo, in Piedmont, Italy, are very closely analogous to the Norwegian occurrences, but the ore bodies are much smaller in size. The mines, which are at Cevia and Sella Bassa, were worked and the ore smelted between the years 1860 and 1870, the smelter being operated by the same company as the Schneeburg works,

Production of nickel from Italian ores.

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(1) Zeit. für. Prak. Geol., 1893, p. 143.

in Saxony. Badoureau gives the production as about 54 tons of metallic nickel a year.(¹)

Occurrence of nickel in Spain.

In Spain, in 1875, they mined 440 tons of ore, but the ore bodies were not operated after 1877 or 1878. The mines which were situated in the province of Malaga, were on small deposits of nickel silicate (pimelite) with 3·96 per cent of nickel.

Deposits of nickel in Russia.

Production of nickel from Russian ores.

At Rewdinsk, in Russia, attempts have been made several times, to mine the deposits of the nickel-magnesia-silicates (rewdinskite) with 4·8 to 19·2 per cent of nickel oxide, but the deposit is small. In 1873, 47·4 tons of ore were mined, and in 1887, 4·9 tons of metallic nickel were produced in the first three months, from which they calculated the yearly production at 40·9 tons of nickel.

Nickel in Wales.

In Wales, in 1882, 38 tons and in 1883, 49 tons of ore were, mined containing 1·4 per cent of cobalt and 0·7 per cent of nickel.

Nickel refining in Great Britain.

Nickel refining is quite an important industry in Great Britain, where a large amount of foreign nickel ore is refined at the various works. The most important of these nickel refineries are at Kirkintilloch (near Glasgow), in Scotland, and at Erdington (near Birmingham) in England. Both of these belong to 'Le Nickel,' of New Caledonia, and are principally using garnierite as ore. Vivian and Sons' old and well known copper and nickel refinery at Swansea, Wales, the Mond Nickel Co's. refineries at Clydach (near Swansea) and Smethwick (near Birmingham), as well as the Wiggin's refinery in Birmingham, are, for the most part, working with foreign nickel sulphide material.

Nickel refining in France.

Nickel at Paris Exhibition.

In France, no nickel ore has been mined, but, after the discovery of the New Caledonia ore, several refineries were erected, the first one being at Septêmes, near Marseilles, where, from 1876 to 1882, experiments were conducted on a large scale, for producing ferro-nickel. Christofle's well known works at St. Denis, near Paris, between 1870 and 1880 produced about 120 tons of metallic nickel yearly. Later on the 'Le Nickel' plant at Havre was erected. The copper plant at Eguilles (Vancluse, near Lyons) has several times conducted experiments in the refining of nickel, and at the Paris exhibition of 1889, several samples were shown produced by bessemerizing according to the Manhés process, which contained from 91 to 95 per cent of pure nickel. (²)

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(1) Annales des Mines, 1877.

(2) J. H. L. Vogt., 'Nikkelforekomster og Nikkelproduktion' Nor. Geol. Soc., Christiana, 1892, pp, 38-40.

Martha and Benno mines in Austria.

Location of mines.

Character of ore.

Composition of ore.

Smelting of Austrian ores

Composition of mattes.

Production of metallic nickel.

Lately, however, the Martha and Benno mines in Silesia, Austria, have produced ore. In 1899, according to the Mineral Industry, only 80 tons of nickel ore were mined, but this rose to 3,896 tons in 1900, and during the half year ending June 30th, 1902, when there were 1,036 laborers employed at the mines and works, the quantity of ore treated was 5,689 tons, which yielded 108 tons of nickel. The mines are situated at Kosemitz, Züsendorf and Gläsendorf, a short distance north of Fraukenstein. They are described by Illner. (1) The ore, which contains from 0·5 to 3 per cent. of nickel, fills fissures in serpentine. Occasionally, these veins carry from 4 to 18 per cent of nickel. Only the two mines, already mentioned are operated, the Martha having two shaft furnaces, capable of treating 50 tons of ore daily. The composition of the ore ranges as follows : SiO_2 60–65·4 per cent ; MgO 8·5–12 per cent ; Fe_2O_3 and Al_2O_3 6–8 per cent ; Ni 2·3–3·5 per cent, and loss on ignition 8–15 per cent. Before smelting, the ore is first mixed with gypsum or with calcium sulphite and limestone, crushed to 12mm. size and pressed into bricks. The shaft furnace is 5m. high, and is charged with the bricks and coke in the proportion of 180 kg. of the former, to 50 kg. of the latter. A very fluid slag is produced, containing 0·3 per cent of nickel, which is used in making slag bricks. The matte composed of about 31·4 per cent of nickel, 49·7 per cent of iron and 14·5 per cent of sulphur, is crushed and subjected to an oxidizing roast, in a two stage reverberatory furnace, which is 6·13m wide, and has a capacity of 300 kg. in eight hours. There are four furnaces of this type, at the works. The roasted matte, containing approximately 65 per cent of nickel 15 per cent of iron and 20 per cent of sulphur is run into a bessemer converter with sufficient sand to slag the iron oxide and is blown for 45 minutes, thus rasing the tenor in nickel to 77·8 per cent. This fine matte is pulverized and treated to a dead roast in the reveberatory, which converts it into a greyish green nickel oxide, containing 77·6 per cent of nickel. This oxide is pulverized, moistened, cut into small cubes, dried and charged with charcoal into fire brick muffles, that are heated in a regenerative gas furnace. After three hours treatment in this furnace, the metal contains 99 per cent of nickel, and 0·3 per cent of iron. The sulphur dioxide, from the roasting, is caught in water and the solution neutralized with lime, the resulting calcium sulphide being used as a flux in the shaft furnace.

Nickel occurs in Greece, Switzerland and Sardinia.

Nickel ore is known to occur in Greece, Switzerland and Sardinia, but in none of these countries, are the deposits large enough to permit of them being mined at a profit.

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(1) Zeit für das Berg-Hutten-und Salinenwesen, No. IV., 1802 p. 816 ; also Mineral Industry, Vol. X. 1901, pp. 485-486, and Vol. XI, 1902, p. 486

NICKEL IN THE UNITED STATES.

Discovery of nickel in United States

The existence of nickel in the United States was probably first made known in 1818, when Seth Hunt opened up the cobalt deposit, near Chatham, Conn. This important announcement was made as the result of an analysis of a trial shipment of this ore to England. (1)

Various attempts to open up mines near Chatham, Conn.

These mines were at first opened for their supposed silver contents as far back as 1661. They were not, however, very remunerative to their successive owners, who in turn tried to operate them. In 1762, they were again tried, and in 1770, several parties associated themselves together for the purpose of operating them for their cobalt contents. In 1787, a quantity of the cobalt was shipped to China. In 1853, a creditable exhibit was made by the Chatham Cobalt Mining Co. of the ore from their mines and its products.

Location of Gap mine.

Perhaps the best known nickel deposit in the United States, is that situated at Lancaster Gap, in Pennsylvania, about three miles south of the main line of the Pennsylvania railroad, and a little over 50 miles west of Philadelphia.

Discovery of Gap mine.

Formation of Gap Mining Co.

Millerite and pyrrhotite regarded as of no value.

Discovery of nickel by Dr. Genth.

According to authentic history, the Gap mines had been worked for their copper prior to the year 1744, and tradition, in the neighborhood, states that they were discovered about the year 1718. For eighty or ninety years, they proved unremunerative to the four or five different companies who tried to operate them, but in 1849, after they had been lying idle for 30 or 40 years, the Gap Mining Company was formed, to again open them up for copper. This company obtained considerable supplies of copper, about enough to pay for running expenses, selling their product to copper smelters in Boston and Baltimore. In all of these earlier operations, the millerite and pyrrhotite were cast aside as useless, being regarded by the miners as ordinary 'mundic' or pyrite. In the beginning of 1852, however, Capt. Doble, who had come to the work, first as a miner, but who, subsequently, became superintendent, was convinced that the material on the dump was not ordinary sulphide of iron, but some other mineral. Analyses of specimens, sent to so-called experts in Boston and Baltimore, were unsatisfactory, so that, in the latter part of 1852, or the beginning of 1853, a sample was sent to Prof. F. A. Genth, who, after analysis, pronounced it to be a nickel ore, at the same time giving the percentage of pure nickel present. The mines, which had hitherto been known as the Gap Copper mines, changed to the 'Gap Nickel mines', but the expenses of mining the ore, and especially the difficulties of the smelting operations, rendered the enterprise too costly, so that the whole of the works were closed down in 1860. (1)

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(1) Whitney. 'The Metallic Wealth of the United States', 1854, p. 497; also Proc. Col. Sc. Soc., Vol. IV., 1891-93, p. 381.

Purchase of Gap mine by Joseph Wharton.

In November 1862, Joseph Wharton acquired possession of the 'Gap mine,' and the deposit became a nickel producer in May, 1863, the ore obtained being treated at the refinery, built by Wharton, at Camden, opposite Philadelphia. The development of the new Caledonia mines had, in 1882, reached such a stage, that the world's consumption of metallic nickel, which had heretofore been about 800 tons per annum, was exceeded by several hundred tons. On account of this over production, prices immediately fell in the forced sales, and Wharton's Camden refinery was obliged to close down about the end of this year. The advent, in large quantities, into the market, of the Sudbury nickel, proved a further disturbing feature, resulting in the final closing of the 'Gap mine' in 1891.

Closing down of Gap mine.

Character and mineralogical composition of rock associated with nickel deposit at Gap mine.

The dark, basic rock, with which the ore body at the Gap mine is associated forms a lenticular mass or stock, extending about 1,500 feet east and west and 500 feet north and south, and lying in the midst of mica schists, of the Georgetown series, of Frazer. The rock consists mostly of green secondary hornblende, and although the change is very thorough, recognizable remains of orthorhombic pyroxene and of olivine were revealed, after careful search through a number of microscopic slides. Reddish-brown biotite is present, and, in some instances considerable plagioclase appears, with occasional accessory titanite. The ore consists of pyrrhotite and chalcopyrite in largest amount, but pyrite is not lacking. Crusts of secondary millerite are also encountered, and often this mineral furnished a not unimportant portion of the nickel contents. Although some ore has been found in bunches within the lens-shaped mass of rock, the productive ground lies near the walls. The ore body is nearly, if not quite vertical, and the depth reached by mining was 250 feet, while, at times, the workings were as much as 30 feet wide. As mined, the ore contains from 1·3 per cent of nickel, 0·25-0·75 per cent of copper, and 0·05 to 0·15 per cent of cobalt. The ore is believed by Prof. Kemp, (from whose description the foregoing information has been obtained) to be the direct result of igneous action, the ore bodies being concentrated, as such, by reason of magmatic differentiation, (2) in this respect resembling the Canadian, Norwegian and Italian occurrences.

Occurrence of millerite.

Situation of ore body.

Extent of mining.

Composition of ore.

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(1) 2nd Geol. Surv. Penn., 'The Geology of Lancaster Co.' CCC., 1880, pp. 163-176.

(2) Trans. Am. Inst. Min. Eng., Vol. XXIV., 1894, pp. 622-631.

Production of nickel from Gap mine.

The 'Gap mine' at one time produced one sixth of the world's supply of nickel, although its total production is only given as 2,000 tons.

Nickel deposits near Webster, North Carolina.

Means of access to Webster occurrences.

Character of Webster ore.

Physical characters of Webster ore.

The nickel deposits, associated with the peridotites of the south-eastern Appalachians, have, from time to time, claimed public attention and several attempts have been made, not only to ascertain their true economic value and extent, but also to develop them to the stage of producing mines. Probably the largest and best known of these occurrences is situated in the vicinity of the town of Webster, the capital of Jackson county, in western North Carolina. The deposits in question, underlie a strip of land, running approximately north and south a distance of about 7,000 feet, and east and west nearly 1,500 feet. The north end of the deposit immediately adjoins, to the east, the town of Webster. The nearest railway station is Dillsboro, on the Murphy branch or division of the Southern Railway, this station being 48·9 miles southwest of Asheville. A wagon road connects Dillsboro and Webster, the distance being about 3·5 miles. The ore is very closely allied to the celebrated garnierite or noumeaite from New Caledonia. It is a hydrous silicate of magnesium and nickel, but very variable in composition, particularly as regards the mutual replacement of nickel and magnesium. It is, therefore, not a homogeneous compound. It is amorphous, filling certain cracks with encrusting, delicate, hemispherical, or stalactitic forms, usually soft and friable, falling to pieces in water, unctuous to the touch, and adhering slightly to the tongue. It varies, in colour, from pale yellowish-green to rather deep apple-green, and depth of colour usually accompanies an increase in the nickel contents.

Analyses of ore from Webster, N.C.

Analyses of Genthite (nickel-gymnite), from Webster, N.C.

	I. %	II %
Silica	49·89	55·38
Nickel oxide	16·60	17·84
Magnesia	22·35	15·62
Water	12·36	10·77
Alumina	.....	....
Fe_2O_3 Iron	.....	0·56
FeO Oxide	0·06	....
Cobalt oxide	.....	.....
Total	101·26	100·17

Authorities for analyses.

Explanation.—I. Analysis of genthite, from Webster, N.C., by Dunnington (Ch. News, 25,270, 1872, and Dana, System of Mineralogy, 6th Ed., 1892, p. 676). II. Analysis by P. H. Walker, (Am. Chem. Jour., 10, 44, 1888, also Dana System of Mineralogy, 6th Ed., 1892, p. 681).

No large amount of very rich ore.

Nickel and cobalt contents of ore.

Geological associations of Webster deposits.

Deposits similar to those of New Caledonia, &c.

Extent of mining development.

Although, as shown, some of the ore contains from 16 to 18 per cent of nickel oxide, no very large amount of similarly rich material could be secured in mining, and most of the rich nickel seams are occupied by greenish nickel silicate, which will assay from 5 to 7 per cent of nickel oxide. Much of this secondary vein matter is mixed with comparatively barren, partially decomposed peridotite, so that it would be impossible to effect a separation, on an economic basis, and the bulk of the material, which could be secured as ore, would assay from 1 50 per cent to 3 per cent of nickel oxide. The ore assaying from 2 to 8 per cent of nickel, contains, in addition, 0·02-0·10 per cent cobalt oxide. These nickel deposits are found in intimate association with a mass of peridotite, made up principally of two varieties, which are, doubtless, differentiates of the same magma, viz.: dunite, made up almost entirely of olivine and chromite, and websterite, composed essentially of bright green diopside, and pale brown bronzite. The mode of occurrence and origin of these deposits, are precisely analogous to those occurring in New Caledonia, Oregon and elsewhere. The development work undertaken, consists of a series of parallel trenches or ditches, which are excavated, in some cases, simply to the solid rock beneath, and, in others, to a uniform depth, in no case exceeding 30 feet. These trenches are designed to give an idea of the relative abundance and disposition of the veins of silicate material. A shaft was sunk, but to what depth has not been learned, while considerable prospecting by diamond drill has also been undertaken.

Nickel in Oregon.

Occurrence of josephinite.

Nickel has, for many years, been known to exist in considerable quantities in southern Oregon, and some of the deposits are regarded as of commercial importance. The mineral josephinite, a nickel-iron compound (Ni. 60·45; Fe. 23·22), has been described by W. H. Melville as occurring in the form of pebbles and smooth boulders, in the placer gravels of a stream in Josephine county, Oregon, which are supposed to have been derived from some dyke of ultra-basic rock, whose location has not yet been discovered.(1)

Nickeliferous pyrrhotite in Jackson and Douglas counties.

Nickeliferous pyrrhotite has also been noticed in both Jackson and Douglas counties, but the nickel silicates of Douglas county are the only ores which appear to be worthy of other than a passing notice.

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(1) Amer. Jour. Sc. Vol. XLIII, 1892, pp. 509-515.

Location of Oregon deposits.

Altitude of Piney mountain.

Mineralogical composition of peridotite associated with the deposits.

Analyses of nickel silicates from Oregon.

The deposits occur near the small village of Riddles, in the southern part of Douglas county, a station on the Oregon and California railway, 226 miles from Portland, and 547 miles from San Francisco. The nickel mines are situated on Piney mountain, about 3 miles west of Riddles, and are connected with this village by an excellent wagon road of easy grades. This mountain, as its name implies, is thickly covered by forest, rising to a height of about 3,400 feet above sea level, occurring as an isolated ridge in a sea of other mountains. It is, approximately, 1½ miles long by 1 mile wide, thus embracing an area of 1½ square miles, in which nickel deposits might be expected to occur. The rocks, underlying this area, is a peridotite or 'saxonite', composed essentially of olivine and enstatite, with a small quantity of accessory chromite and magnetite. The olivine predominates, forming more than two-thirds of the mass of the rock. The ore is a silicate of nickel and magnesium, and, as usual, very variable in composition. The mode of occurrence and origin of ores of this class, have already been discussed in detail, and the Oregon occurrence presents no unusual features which are worthy of special or extended reference. The following analyses, of carefully selected material, well illustrate the chemical composition of the pure nickel mineral, but the bulk of the ore which could be economically secured and utilized, would, of course, be much lower in nickel contents.

	I.	II.	III.
Loss at 110° C.	8·87	6.63	7·00
Loss on ignition	6·99	....	....
Al_2O_3 & Fe_2O_3	1·18	1·38	1·33
SiO_2	44·73	48·21	40·55
MgO	10·56	19·90	21·70
NiO	27·57	23·88	29·66
Total......	99·90	100·00	100·24

Explanation.—Analysis I, is by F. W. Clarke, (Am. Jour. Sc., Vol. XXXV, pp. 468-487; Nos. II and III are by Dr. Hood, (Min. Res. U. S., 1883, p. 404.)

Discovery of Oregon deposits.

The first discovery of these deposits was in 1864, and, in the fall of 1881, Mr. W. Q. Brown secured control of what appeared to be the most valuable portion, transferring his interest to an incorporated company, known as the 'Oregon Nickel Mines'. It is stated that about $30,000 was expended in development work. In 1891, some of the nickel bearing area was secured by a Chicago corporation, called the 'International Nickel Mining Co,' which is said to have expended about $60,000 on development work. Extensive preparations were made to mine and smelt this ore, but much of the smelting and other machinery purchased, was never even set in position. The Anglo-American Nickel Co., incorporated in 1893, and the Oregon Nickel Mining Co., also own property in this neighbourhood. The amount of development work done, in connection with these deposits, is hardly sufficient to test their commercial capabilities. Numerous open cuts, short tunnels and shallow shafts from 20-40 feet deep, have been made, but nowhere has a vertical depth of over 50 feet been reached. ([1])

Mining development work.

Extent of mining development work.

The Gem mine, in Fremont county, Colorado, may be mentioned at some length, in this connection, as it is very similar, in mineralogical composition, to the Haileybury occurrences discovered last autumn in Northern Ontario. The vein at the Gem mine is in hornblende schist, and the ores were principally copper, but nickel soon made its appearance, and at a depth of 15-20 feet became quite prominent. From the surface, down to a depth of 75 feet, the vein has an average width of 3·5-4 feet. At this point, it pinched out, and, with the exception of a narrow streak of ore, which may be its continuation, and which contained the same cobalt and nickel minerals, no further ore was encountered lower down. The nickel-cobalt minerals of this mine are accompanied by native silver, some of the mineral specimens being occasionally so permeated by fine wire silver as to be broken with difficulty. In 1882, 12 tons of ore, containing 12 per cent of nickel, and 2-2·5 per cent of cobalt, with considerable chalcocite, were shipped. Later, about half a ton of selected ore, containing 34 per cent of nickel and 3-4 per cent of cobalt, were sent to Swansea, England. The mine, however, was involved in litigation, and the ore body was seemingly too small for any extended mining operations. ([2])

Nickel in Colorado.

Similarity to Haileybury occurrences.

Depth of deposit.

Character of ore.

Production of ore from Gem mine.

Reasons for closing down.

Since the closing down of the Lancaster Gap mine, the entire United States production of nickel, from domestic ores, has been derived from Mine la Motte, Mo., the metal being secured as a by-product in the treatment of lead ores. In 1899, this production amounted to 22,500 lbs., but in 1901, it had decreased to 6,700 lbs., while in 1902, the 20 tons of matte, containing nickel and cobalt, which were refined at the works of the Mine la Motte Lead and Smelting Co., yielded 5,748 pounds of metallic nickel. ([3])

Nickel now produced in U.S. all from ores of Mine la Motte.

Production of nickel from Mine la Motte.

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(1) Dr. W. L. Austin. 'The Nickel Deposits near Riddles' Oregon'. Proc. Col. Sc. Soc., Vol. V., 1894-96, pp. 173-196.

(2) Thomas Charlton, Proc. Col. Sc. Soc., Vol. IV., 1891-93, pp. 420-421.

(3) Min. Res. U.S., 1902, pp. 265,266.

NICKEL IN NEW CALEDONIA.

Reasons for celebrity of New Caledonia deposits.

The nickel deposits of New Caledonia have, for many years, enjoyed an enviable reputation, not only for the large and continuous supply of ore they have produced, but also for the high grade they have been able to furnish for purposes of export. From about the year 1880, to 1888, these mines produced from two-thirds to three-fourths of all the nickel in the market. From the latter year, however, the mines of Canada have been gradually increasing their output, and, in spite of many adverse circumstances, it is believed that, at the present time, the amount of nickel secured from Canadian sulphide ore, is considerably in excess of that produced from the New Caledonia silicates.

Production of Canada exceeds that of New Caledonia.

General character and mineralogical associations of New Caledonia silicates.

The only nickel ore that occurs in New Caledonia is a hydrated silicate of nickel, in which more or less of the nickel oxide is replaced by magnesia, ferric oxide and alumina. The ore is associated with chalcedony, a magnesian silicate resembling meerschaum or sepiolite, limonite or bog iron ore and serpentine. In addition to these, there are usually small quantities of chromite and asbolite. The mineral is entirely free from sulphur, arsenic or copper, and, although, in the first instance the deposits were regarded as the gossan-like material produced by the sub-aerial decay of nickeliferous sulphides, the extensive workings already undertaken have failed to reveal any traces of such material even in the deepest workings.

Early misconceptions.

Discovery of garnierite in 1865.

The mineral garnierite or noumeaite, characteristic of these deposits, was discovered by M. Jules Garnier, in 1865, and was noticed by him in 1867, (1) and was described by Liversidge in 1874 (2). The mineral is closely related to the nickel-gymnite, described by Genth, in 1851, and for which the name genthite was proposed by Dana, in 1867.

Chemical analyses of garnierite and related silicates.

As the following analyses will show, it is very variable in chemical composition. The material analyzed was selected with great care, and will give a good idea of the composition of the purest varieties of garnierite as well as its intimate connection with sepiolite, or silicate of magnesia, with which it is associated, and into which it passes by insensible gradations.

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(1) Bull. Soc. Geol. de France, Vol. XXIV, p. 438, Paris, 1867.

(2) Jour. Chem. Soc., Vol. XII, p. 613, July, 1874.

ANALYSES OF GARNIERITE FROM NEW CALEDONIA.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Silica	35·45	44·40	37·78	38·35	47·24	50·00	48·00	50·15	51·94	53·80	41·80
Nickel oxide	45·15	38·61	33·91	32·52	24·01	18·50	15·39	10·20	2·32	0·24	......
Magnesia	2·47	3·45	10·66	10·61	21·66	15·80	16·92	17·43	21·35	24·82	37·38
Water	15·55	10·34	15·83	17·97	5·27	10·00	20·75	21·65	23·17	21·47	20·39
Alumina	......	......	......	0·40	1·67	......	......	......	1·36	......	......
	0·50	1·68	1·57	......	......	......	......	0·57	......	......	1·26
Iron Oxide Fe_2O_3	......	......	......	1·15	......	3·50	......	......	......	......	......
Iron Oxide FeO.	......	0·43	......	......	......	......	......	......	......	......	......
Cao	......	1·07	......	......	Traces.	2·70	......	......	......	......	......
	99·12	99·98	99·75	100·00	99·85	100·50	101·06	100·00	100·14	100·33	100·83

Authorities for chemical analyses.

Explanation. I. Analysis by Dann (Ber. Nied. Ges., Jan. 7, 1878). II. Analysis by Garnier (Comptes Rendus, 86,684, 1878). III. Analysis by Kiepenheuer (Ber. Nied. Gest., July, 14, 1879). IV. Analysis of dark green garnierite, from Nakety, by Liversidge (Minerals of New South Wales). V. and VI. Analyses by Garnier (Soc. des Ingrs. Civils, 1887). VII. Analysis of a translucent, pale green variety, from Oüaillon, by Liversidge. VIII. Analysis of similar mineral from same locality, by Liversidge. IX. A very pale-green variety from Bel Air mine, Kanala, by Liversidge. X. Another similar specimen from same locality. XI. Analysis by Garnier of white veins, in the green mineral (garnierite), resembling sepiolite.

Ore at first to contain from 12 to 15% of nickel.

Average composition of New Caledonia ores from shipments.

Ore at first thrown away is now being used.

Variation in composition of the ore.

Average composition of New Caledonia ores.

At first, when mining operations were started, it was stipulated that the ore should contain from 12 to 15 per cent nickel, but now, the minimum has been reduced to 7 per cent and it is stated to be difficult to secure more than 60,000 to 70,000 tons per annum of such a grade of ore, although, if the European smelters would lower their limit to 5·5 per cent, the production could be more than doubled. From 1875 to 1884, R. Flechner has calculated that 8·3 per cent of nickel was the average contained in the ore, while Du Peloux states that in 1884, 850 tons of metal were produced, from 12,000 tons of ore, thus giving an average of 7·1 per cent. Croissille states that between 1880-85, 28,933 tons of ore were produced with an average of 10·5 per cent nickel. In the first years, a large amount of ore, containing from 3 to 11 per cent nickel, was discarded as valueless for purposes of export but lately, these dumps have been overhauled and some of the material shipped. The largest New Caledonia company 'Le Nickel' in its catalogue, issued at Paris, in 1889, stated that the various grades of their ore contained 8, 10 and 12 per cent of nickel. From 1876 to the present time, the ore has varied in composition, as shown under I; under II, is given the composition of the ore, which was being shipped to Europe in 1876; under III, the average composition of New Caledonia smelting ore, (according to Levat); under IV, is given the average composition of th nickel ore, as it was shipped in 1899, according to E. A. Wineberg (Min. Industry, Vol. VIII, 1900, p. 435.

	I.	II.	III.	IV.
	%	%	%	%
Nickel oxide	9 to 17	18·00	7 to 8	10·00
Silica	41 to 46	38·00	45 to 50	42·00
Iron oxide	5 to 14	7·00	14 to 16	10·50
Alumina	1 to 7	....	3 to 5	2·50
Magnesia	6 to 9	15·00	10 to 12	22·00
Water	8 to 16	22·00	14·00	12·00
Lime	......	.....	....	1·00

Average nickel contents of New Caledonia ore at present shipped.

The nickel contents of the New Caledonia garnierite, lately smelted, has averaged about 7 per cent of nickel, but each succeeding year sees a poorer product handled and shipped.

Mode of occurrence of New Caledonia deposits.

Altitude of hills on which deposits occur.

Transportation difficult.

Character of ore bodies.

Secondary origin of nickel silicates.

Irregularity of deposits.

Deposits are comparatively shallow.

Deposits cover a large area.

Methods of mining.

Transportation.

The ore is intimately associated with a peridotite, and its various decomposition products, grouped together under the name of serpentine. Fresh, undecomposed pieces of this rock, made up chiefly of olivine, are said to contain as high as 1 per cent of nickel. These serpentines, which cover the larger portion of the area of the island, rise into a series of hills, which are from 400 to 4,000 feet above the sea, the general elevation being about 2,000 feet. The deposits generally occur on the tops of these mountains, so that transportation of the ore, mining materials and supplies is very tedious and difficult, and in many cases, expensive roads and aerial rope-ways have been constructed to deposits which, in some cases, came far from realizing expectations as to extent and richness. The ore bodies occur as veritable 'stockworks', cutting the decomposed peridotite in all directions. Invariably, where the nickel occurs, the surface is covered with a highly ferruginous soil, in which pisolitic iron ore is very abundant. Although this decomposed remnant of the peridotite contains a little nickel, most of the nickel has been leached out, to be deposited in secondary veins of nickel silicate, in locations at various depths below, favourable places for such concentrations being in the vicinity of faulting and jointing planes. The veins vary in size, from a few inches to as much as thirty feet, but they are exceedingly irregular in this respect, at one time becoming gradually narrow, while, in other cases, large deposits end abruptly against barren rock. These veins or deposits are comparatively shallow. It is true, that one fissure was followed down about 600 feet in depth, but generally the veins give out from 75 to 100 feet below the surface. Without reference to the surface mantle or covering, from which most if not all of the nickel has been removed by leaching, the richest deposits are those nearest the surface, while the higher parts of any deposit are richer than those lower down. The comparative shallowness of the deposits is, however, compensated by the large areas they cover, and some of the mines have yielded from 30,000 to 100,000 tons of ore, and are still in operation. The mining is carried on by means of open cut work, the ore being secured by means of a series of benches. The pick and shovel are usually sufficient to loosen and remove the ore, but occasional blasting is sometimes necessary. The ore, when properly mixed, is carried, by means of aerial rope-ways to ground tramlines, from which it is transported by lighters to the ships.

Various methods of extracting nickel.

Various methods, for the extraction of nickel from these ores have been attempted. Garnier, whose name has been associated with these deposits from the date of their discovery, tried to smelt the ore directly to a nickeliferous pig iron, which was afterwards to be refined in a reverberatory furnace to ferro-nickel. The first part of the process proved satisfactory, and the nickel-iron pig, obtained from the richer lumps contained from 65-68 per cent of nickel, 23-29·5 per cent of iron, 1·5-2·5 per cent of sulphur, 3·5-5·5 per cent of silica and carbon occurring as graphite and from 1·5 to 2·5 per cent of other impurities, and amongst them, phosphorus. It was found impossible to economically handle or to refine this product owing to the presence of sulphur, which has a strong affinity for nickel. Various wet methods were then employed, which followed, on a large scale, the different operations used in making chemical analyses. The ore was first dissolved in acid and the metals removed by the use of lime or bleaching powder, and finally a solution, containing nickel alone, was obtained. From such a condition it is easy to produce the nickel, by fusing with charcoal the dried nickel salt.

Nickeliferous pig iron.

Composition of nickel-iron pig.

Difficulty of refining product.

Method of obtaining metallic nickel.

Later on, however, they adopted a dry method, in the preliminary stages. In the first years, they smelted it with the addition of a special Norwegian pyrrhotite, containing nickel and copper. In order to remove the excess of iron and copper, they now smelt the ore in low water-jacketed blast furnaces, with materials containing sulphur (calcium sulphide obtained in the manufacture of soda by the Le Blanc process), or with gypsum. The gypsum, which is made up of both lime and sulphur, is reduced, the sulphur uniting with the nickel by reason of its greater affinity for this metal, while a portion of it is taken up by part of the iron, the rest of it combining with the silica, magnesia and lime, and the rest of the iron to form a slag. This slag contains about 48 per cent of silica, 12-13 per cent of iron and not more than 0·40 to 0·45 per cent of nickel. The nickel-iron matte contains about 50-55 per cent of nickel, 25-30 per cent of iron and 16-18 per cent of sulphur. This matte, by reason of its greater specific gravity sinks to the bottom, permitting the lighter slag to be drawn off. This matte is, in turn, roasted and a portion of the sulphur thus removed. It is re-smelted with sand, and the nickel will again combine with by far the larger share of the sulphur, leaving a comparatively small proportion for the iron, while the remainder of the iron combines with the silica or sand to form a slag. By a repetition of these, or similar methods, the iron is finally removed, leaving a compound made up essentially of nickel and sulphur, which is roasted with nitrate of soda to produce nickel oxide. This is then mixed with charcoal, and reduced, by the application of intense heat, to metallic nickel.

Later methods for refining nickel ores.

Explanation of reactions.

Composition of slag and nickel-iron matte.

Methods of producing nickel oxide and metallic nickel.

Refineries first erected in New Caledonia.

Attempts have been made, from time to time, to partially refine these ores in New Caledonia, and blast furnaces were erected and in operation, both at Noumea and Thio, as well as at Newcastle, in New South Wales, but the difficulties of procuring coke, suitable flux and labour have hindered their progress and most of the ore at least is now exported for smelting and refining purposes. Most of this ore is refined in France, where 'Le Nickel' company have extensive refineries at Havre, but a large proportion is also refined at Kirkintilloch (near Glasgow), in Scotland, Erdington (near Birmingham), in England and at Iserlohn (Westphalia), in Prussia. The Engineering and Mining Journal of May 20, 1899, notes that a cargo of 3,000 tons of New Caledonia ore, is being sampled for the Orford Copper Co., the ore averaging 7 per cent nickel. The merging of the Nickel Corporation, Limited, and the Société Minière Caledonienne, of New Caledonia, as part of the International Nickel Co., will result in the smelting, by this company, of a considerable amount of New Caledonia ore, at their refinery at Constable Hook, N.J.

Ore now refined in Europe.

Some New Caledonia ore refined in United States

First active mining operations.

Although these deposits were discovered in 1865, it was not until 1873 that active mining operations were undertaken. In 1880, the Société le Nickel acquired the celebrated mines at Thio, but did not commence mining until 1887.

The following figures represent the production of ore and nickel from the New Caledonia mines.

PRODUCTION OF ORE AND NICKEL FROM NEW CALEDONIA.

Production of ore and nickel from New Caledonia mines

Year.	Ore mined.	Ore exported.	Nickel contents.	Nickel contents.
	Tons.	Tons.	Tons.	Tons.
1875	327	....	....	
1876	3,406	....	....	
1877	4,377	....	....	
1878	155	....	.....	
1879		....	....	
1880	2,528	....	210	
1881	4,070	....	388	
1882	9,025	....	749	
1883	6,881	....	561	
1884	10,838	....	904	
1885	5,228	....	850	
1886	920	....	150 ?	
1887	8,602	....	1,350 ?	

PRODUCTION OF ORE AND NICKEL FROM NEW CALEDONIA.—*Con.*

Year	Ore mined.	Ore exported.	Nickel contents.	Nickel contents.
	Tons.	Tons.	Tons.	Tons.
1888	6,616	......	900 ?	
1889	19,741	......	1,381	
1890	22,690	......	1,633	
1891	35,000	......	2,449	
1892	......	......	1,244	
1893	69,614	45,614	2,493	
1894	61,243	40,089	2,422	
1895	29,623	38,976	2,548*	(2,548)
1896	6,417	37,467	2,972*	(2,707)
1897	26,464	57,439	2,858*	(2,858)
1898	53,200	74,614	3,608*	(4,205)
1899	103,908	103,908	3,845*	(4,205)
1900	.....	100,319	4,676*	(4,526)
1901	.....	132,811	6,202*	(5,210)
1902	......	......	....	(3,620)

* Nickel contents of ore refined in Europe, according to Mineral Industry. The figures in brackets, are production of nickel from New Caledonia ores, in France, Germany and England (according to Metallgesellschaft and Metallurgische Gesellschaft, August 1903, p. 23.)

METHODS OF MINING AT SUDBURY.

Methods of mining in Sudbury District.

Occasional accidents owing to imperfect timbering.

Every reasonable precaution now being taken to ensure safety to miners.

The methods usually employed throughout the Sudbury District for obtaining the requisite supply of ore, consist, partly, in the sinking of shafts and the opening up of the ore body, by means of underground levels, drifts and stopes, the whole of such mining operations being carried on under a solid roof. For this work, very little timbering is required, although, in some cases, serious accidents, involving the loss of one or more human lives, have resulted from neglecting to provide even the small amount of timbering necessary, where occasional slips, faults or slickensides occur. As a rule, however, the walls and roof are very solid, and, at the present time, every reasonable precaution is taken to guard against such accidents, by frequent, careful and systematic scaling, removing all loose or menacing portions of rock or ore. The larger part of the ore, however, is secured by a combination of this method and a system of open cast work. This, which, in reality, is a species of deep quarrying, is a very cheap and effective method of obtaining large supplies of ore, and these considerations, no doubt, contributed to its adoption in the first place. On the other hand, these open pits being exposed to the weather, work is, at times, carried on only with extreme discomfort to the men, or is even seriously interrupted during periods of extreme cold or otherwise inclement weather. At the same time, it is open to the serious objection, that it is much more dangerous to the men, and, in spite of the most careful inspection and frequent scaling, large bodies of rock and ore are liable to be detached by the action of frost, gravity or other agencies. Lately, a disposition has gradually developed, to abandon in large measure, much of the open mining, and to remove the ore by means of levels and stopes at regular intervals, beneath these pit floors, cross-cutting the ore body frequently by a series of drifts. Finally, after breaking away overhead, and providing an arched roof, the whole is stoped away to the level below, and the ore hoisted from thence by means of shafts. Only such pillars and supports, as are necessary will remain standing, and the intervening spaces will be filled by rock and ore too lean to be utilized, the whole being supplemented, when necessary, by material from the dumps.

Mining chiefly done by open-cast work or deep quarrying.

Drawbacks to use of open pits.

Lately more usual mining methods adopted.

The system of open cast work, which has hitherto found most favour in the district, consists, first, in the sinking of a shaft of the required dimensions, at varying angles, this inclination being governed, mainly, by the general dip and direction of the ore body. This shaft secures the necessary accommodation for the skipway for hoisting the ore, while, at the same time, it provides a manway for ingress to or egress from the underground workings, by means of ladders, with landings at frequent intervals.

Explanation of open pit mining methods.

The largest pit in the district is at the Creighton mine, where on the first of June last (1904), ore was being hoisted from an open cut or quarry, measuring about 350 feet long, by 275 feet wide and 62 feet deep. The pit, known as No. 2 mine, of the Canadian Copper Company, at the end of January, 1903, was opened up on a chimney of ore, which, below the 200-foot level is growing larger. At the bottom of the open pit, which has reached the third level, at 217 feet below the surface, the average diameter is 120 feet. The new vertical shaft had, at the same time, reached a depth of 390 feet, the fifth level being at 374 feet. At the Victoria mine, the main shaft has been sunk to a depth of 557 feet, with various levels, drifts and stopes. The west open pit at this mine measures 70 by 125 feet at the surface, gradually tapering to 50 by 100 feet at the first level.

Creighton mine is the largest open pit in district.

Dimensions o pit at No. mine.

Size of pits a Victoria mine.

Each mine is provided with a rock house, as soon as its permanency is established, and a double skiproad leading to it from the mine. The

Equipment of rock houses.

Ore sledged to proper size for crusher.

Use and capacity of Blake crusher.

Use of trommel screen and oscillating tables in sizing ore.

Different sizes fall into separate bins.

Number and extent of Copper Cliff roast yards.

Main roast yard near Clarabelle junction.

Size and capacity of main roast yard.

steel skips having a capacity of 1½ tons each, are hoisted to the top of the rockhouse, dumping automatically, on a large inclined 'grizzly' sizing-screen, which separates the fine from the coarse ore. Most of the ore is sledged to a proper size for the crusher in the mine, although, sometimes, this operation takes place on the floor of the rock house The coarse ore falls near the mouth of the 15 x 9 Blake crusher, set to about 1¾ inches, which has a capacity of about 20 tons per hour, (or 400 tons for the usual two shifts, of 10 hours each). Occasionally, as at the Creighton mine, there are two of these Blake crushers, but usually one is considered sufficient. The ore is then passed into the upper end of a slightly inclined revolving trommel screen, where it is sized into three classes, for the succeeding operation of roasting. The fines pass through ¾ inch mesh holes in the trommel screen, the medium or ragging, through 1¾ inch holes, while the coarse is discharged at the lower end of the screen and is caught on an oscillating sorting table, also slightly inclined lengthwise. The jerking motion of this table provides such a rate of travel of the pieces of ore, as enables a certain number of boys, stationed along the side, to pick out, and cast aside, a considerable proportion of barren rock or very lean ore, at the same time permitting the purer and higher grades to continue their journey to the ore bins. Each of these sizes falls into a separate series of bins, from which ore of the required class is automatically loaded, by means of inclined steel chutes, into standard gauge cars, and hauled by locomotives to the roasting yards. At the time the surveys for the Copper Cliff mines area were being carried on, there were three roasting yards. The old one, which was graded by Dr. E. D. Peters, is situated immediately west of the old or East Smelter, and measures roughly 2000 feet long and 125 feet wide. This still remains in use, and by the removal of the East Smelter buildings, which is about accomplished, this will be increased to 3000 feet. For some years, a small roast yard, was utilized about midway between the original Copper Cliff mine and the Ontario Smelting Works. The site of this, which measured about 1000 feet by 125 feet, is shown on the large scale maps, but it has now been abandoned, as its situation so close to the works and residences, at times occasioned great discomfort to the workmen and inhabitants. The main roast yard which is in use at present, and which is capable of much greater expansion, is located to the northeast of the West Smelter towards the Manitoulin and North Shore railway. At the time the surveys were made, it was about 2700 feet, long by 150 feet wide, and it could be very readily extended to measure 4000 feet. It will thus be seen, that without any great effort, roasting ground, with a capacity of from 250,000 to 300,000 tons, is already available. Many of the mines situated at Copper

Cliff, are, of course, handy to the roast yards, but most of the ore at present being utilized by the Canadian Copper Company, is brought from the Creighton mine, coming over the Manitoulin and North Shore railway, a distance of about 7½ miles to Clarabelle Junction, about a mile northeast of the main roast yard. The ore from the Stobie mine has to be brought by a branch railway to Sudbury, a distance of about 3½ miles and then down the 'Sault' branch of the Canadian Pacific railway to the southern roast yard at Copper Cliff, a further distance of about 4 miles. The ore from the Frood, or No. 3 mine, has to be hauled first to the Stobie mine, by a spur about 1·25 miles long, and thence, by the same route from the Stobie mine to Copper Cliff. Neither of these mines are, however, in operation, as an abundant supply of very high grade ore, is more easily procurable at the Creighton mine. At the Victoria mines, of the Mond Nickel Company, an aerial tramway carries the ore from the mine to the roast yard, and thence to the smelter.

Creighton mine ore has to be hauled about 8½ miles.

Ore from the Stobie and Frood mines is hauled considerable distances.

METALLURGY.

In the production of nickel and copper from a sulphide ore, the following operations have to be considered.

Operations necessary for the production of nickel exide and nickel.

1. Treatment of the ores, for low grade copper-nickel matte.

2. Treatment of the copper-nickel matte, for concentrated copper-nickel matte.

3. Treatment of this matte, for copper-nickel alloys.

4. Treatment of the concentrated copper-nickel matte, for nickel matte.

5. Treatment of the nickel matte, for nickel oxide and metallic nickel.

The first two of these operations are carried out at the smelting works in the Sudbury District.

ROASTING.

The metallurgical treatment of this ore commences at the roast yard, whither it is conveyed from the mines, and being piled in convenient heaps, on previously laid cordwood, is exposed at high temperatures, without fusion, or at most, incipient fusion, to the action of currents of air. The object of this roasting, is to bring about the oxidation of the iron, and incidentally of the sulphur, as complete as is possible without involving an undue loss of metal, in the slags of the following smelting, and second, the expulsion of arsenic, if any should happen to

Roasting first step in metallurgical treatment.

Objects of the roasting.

With rare exceptions no arsenic in Sudbury ores.

Care has to be exercised in oxidizing the ore and in building roast yards.

Levelling and draining of surface.

Precautions taken to prevent loss of nickel and copper.

Proportion of loss of metals not known.

Analyses of copper-nickel stalactites.

Water of marshes contains copper.

be present. With the possible exception of the Worthington mine, and some other deposits in that vicinity, none of the ore of the Sudbury District contains any appreciable amount of arsenic or antimony. If the oxidation be very imperfect, the resulting matte will contain so much iron, that its bringing forward will be unduly costly, while if the oxidation be too thorough, an undue loss will occur on smelting the roasted ore. At Copper Cliff and at Victoria mines, the Canadian Copper Company and Mond Nickel Company, have spared neither trouble nor expense in the construction and equipment of their roast yards. The sites selected, consisted of flats or swamps, which have been further graded or filled up, any natural roughness or unevenness being cleared away and levelled, and the whole being given a gentle slope, with carefully made drains, serves to remove, at once, any rain or surface water. These precautions have to be taken, to prevent loss of metal as soluble sulphates. It has been frequently stated, that any great loss is thus fully guarded against, but, so far as known, no deliberate attempts have been made to determine what amount is thus actually carried off by rain and melting snow. After the heap has been fired, a crust rapidly forms, which is believed to give further assistance against loss, but during heavy or long continued wet and stormy weather, it is believed an appreciable amount is thus removed. Whether the saving of this is a commercial possibility, is well within the range of experiment. Hollows in the burnt out heaps are filled with stalactites, an analysis of one of which gave Mr. Donald Locke, the following composition Cu O, 8·42 per cent; Ni O, 10·21 per cent; Fe O, 7·18 per cent and $S O_3$ 27·53 per cent. The water too, of the marsh adjoining, has a decided bluish tinge, and an iron object immersed in it, is immediately covered with a thin coating of copper.

Open air heap roasting cheap and effective.

Sulphur cannot be economically saved.

Open air heap roasting, as practised at Sudbury, is, with favourable weather conditions, an old, simple, cheap and very effective method of treatment, for the elimination of the undesired surplus of sulphur, from low grade sulphide ores. Experiments and trials have been made, to profitably save this sulphur, by present methods, but the sulphur contents, averaging from 16 to 30 per cent, and, for the most part, approaching, in this respect, the first mentioned figure, with iron from 33 to a little over 50 per cent, is, apparently, too low to permit of its economic winning.

Experiments to make use of pyrrhotite for the production of sulphurous

Titus Ulké (1) states that, 'during 1902, was demonstrated the commercial impracticability of cheaply roasting Sudbury pyrrhotite nickel ores, which do not average over 25 per cent of sulphur, in Herreshoff furnaces, in order to utilize the sulphurous acid gas thus obtained, to make sulphite pulp or liquid acid. The use of the dead roasted residue, in the making of ferro-nickel, was also found to be commercially unsuccessful. It is recognized that, unless this roasting in the Herreshoff furnace can be done mainly without the aid of extraneous heat, the cost, compared with heap roasting, is prohibitive, and that, in any case, the average percentage of sulphurous acid in the gas produced, is too low to be economical for use in the manufacture of calcium bisulphite for making sulphite pulp.'. On the other hand, Mr. E. A. Sjostedt (²) metallurgist to the Lake Superior Power Company, who initiated and carried on these trials, states that the process has been worked out in a satisfactory manner, the pyrrhotite being roasted without extraneous heat, and yielding sulphurous acid in quantities that more than repay the cost of converting the raw ore into briquettes.

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(1) Min. Industry, Vol. XI, 1903, p. 490.

acid and ferro-nickei not commercially successful according to Ulké.

Sjostedt holds the reverse opinion based on practical experience.

The results of operations for two weeks in 1903, showed an average recovery of 86·4 per cent of sulphur, and a total working cost of $1.86 per ton of ore. Such are the conflicting statements of experts, who have been concerned in the practical working out of the process, but the popular opinion seems general, that failure has followed these elaborate trials, which had the advantage of being conducted on a commercial basis, by skilled men, with every modern appliance to ensure success. The fact that the Lake Superior Power Company, during their later operations in the Sudbury District, had practically adopted the general system of heap roasting and smelting, seems to lend support to the view expressed by Mr. Ulké.

Adoption of ordinary smelting methods argues the lack of success in experiments.

The sulphurous fumes from the roast heaps, have destroyed most of the vegetation, from within an area of between one and two miles of Copper Cliff, and have a very injurious effect on vegetation, and especially young and tender trees and plants, as far as the town of Sudbury. In the immediate vicinity of Copper Cliff, the destruction wrought to all growing plants and trees is very complete, and a more desolate scene can hardly be imagined, than the fine white clay or silt of the flats, through which protrude, at intervals, rough rocky hills, with no trees, or even a blade of grass, to break the monotony. Of late years, vegetation has, so to speak, become accustomed to the sulphur, and gradually, and as a result, the area affected by the fumes is becoming more circumscribed. The maple seems to withstand the sulphur the best, and trees of this species may be found fairly green in the immediate proximity of the roast yards. To add to this scene of desolation, the houses are of wood, rarely painted, while most of the area is covered with half-decayed logs, stumps and upturned roots, all of which have a peculiar brownish tinge, the result of the sulphur, which acts as an

Destruction of vegetation by sulphur fumes.

Injury done at Copper Cliff.

Vegetation becomes accustomed to sulphur.

Maple withstands the fumes the best.

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(2) Eng. & Min. Jour., April, 25th, 1903.

Iron objects rapidly eaten away.

Removal of one of the roast yards.

excellent preservative. On the other hand, all the barbed-wire fences, telegraph lines and other iron objects are rusted, and rapidly eaten away, requiring to be frequently replaced. The removal of one of the roast yards, has had a most marked effect, and the beneficial results which were sure to follow, are even now beginning to be apparent, for the two remaining are situated to the east and northeast of the town and thus the prevailing winds, which are from the southwest, will tend to carry the fumes away. With the persistent influence and guidance of the president and general manager, Mr. A. P. Turner, trees are being planted, certain areas graded and made into lawns, roads opened up and culverts and bridges fixed, while the tortuous course of a small stream, running through the town, has been straightened and deepened. It is hoped that these efforts at beautifying the place, will meet with the success they deserve, and already the town has taken on a new appearance, due to these improvements. The fumes, which are free from arsenic, seem to have no injurious effect on man or beast, except on occasions, when particularly dense and accompanied by fog, when they produce a peculiar strangling or choking sensation, accompanied, on rare occasions, by bleeding at the nose. The residents are all seemingly healthy, and suffer from no unusual complaints, while some even assert that the sulphur is a positive cure for catarrh, consumption, and kindred diseases. People, moreover, at first, complain of a strangling sensation, but this gradually disappears, and those, who have resided there for a time, miss the sulphur when removed to another place, and have even an ill defined though rarely expressed longing for this seemingly heavy and satisfying atmosphere.

Improvements at Copper Cliff.

Sulphur fumes have no injurious effects on man or beast.

Sensations produced by sulphur fumes.

Erection of roasting shed.

At the Murray mine, a huge shed, with numerous large chimneys, was erected, for the purpose of roasting the ore during the winter, but it was not a success in any respect. No great thought or care, has in the past, marked the efforts of some of the companies, in the selection of a site for the roast yard, and the ore has been placed in heaps, where the natural surface of the ground permitted, with scarcely any previous preparation, such as grading and draining. The mechanical loss, alone, from such carelessness, must have been far from negligible. The main supply of fuel that can be secured and is used for the heap roasting, is dead or dry pine, often still standing as tall bare rampikes, the remains of extensive fires which swept over the area about thirty-five years ago. This during the first years of the operations, could be secured very readily and cheaply, but the extensive and continuous roasting has used up all available sources of supply close at hand, and this wood has now to to be brought considerable distances by rail, and is now often mixed with ordinary cordwood. At the Victoria mines,

Carelessness at first in location and construction of roast yards.

Dry pine main fuel used in roasting.

Large consumption of fuel.

however, there is an abundant supply of this dry pine for years to come, and it is brought in by teams and sleighs during the winter, from the area immediately adjoining. This dry pine is very efficient for this purpose, as it is readily kindled, and produces almost immediately a short though fierce heat, which serves to ignite the pile thoroughly, and this, once started, continues burning, on account of its sulphur contents.

Dry pine plentiful at Victoria mine.

Suitability of dry pine for roasting.

The roast heaps are rectangular in shape, varying in size from 40 by 60 feet, and 7 feet high, to 60 by 120 feet and 18 feet high, and containing, in general, from 200 to over 3,000 tons of ore. The small heaps of 200 tons are of 'spilt matte,' of which mention will again be made. Ore heaps are not less than about 600 tons. Heaps of from 800 to 1,000 tons should burn out in from 40 to 50 days, the larger heap taking, in general, from 3 to 4 months, while occasional heaps containing 4,000 tons, which are the largest yet attempted, and which were by no means a brilliant success, have been known to burn from 6 to 7 months. The ore is piled on a bed of split wood, about one cord being used to twenty tons of ore. This wood serves to start the oxidation of the sulphur, iron, nickel and copper, the sulphur to sulphurous acid, the iron to iron oxide, the nickel and copper chiefly to sulphates. The sulphur, which, in general, averages about 25 per cent, is reduced to about 6 or 8 per cent, while the iron is, in large part, oxidized to ferrous oxide, and the associated norite or gangue is rendered more or less porous or disintegrated by the swelling and oxidation of the ore. An analysis of roasted ore, in December, 1888, gave F. L. Sperry 5·40 per cent of copper, 2·43 per cent of nickel 7·92 per cent of sulphur and 25 per cent of iron and the rest gangue, chiefly norite or diorite. L. P. Silver (1) states that an average sample of the roasted ore gave 3·25 per cent of copper, 2·16 per cent of nickel, 8.32 per cent of sulphur, 25·61 per cent of iron and the rest gangue.

Construction and size of roast heaps.

Amount of ore in roast heaps.

Duration of roasting.

Amount of fuel used.

Reduction in amount of sulphur.

Analyses of roasted ore.

Donald Locke says, that the roasted ore, in 1902, being used by the Canadian Copper Company, assayed about 1.5 per cent of copper, 2.5 per cent of nickel, 6 per cent of sulphur and 26 per cent of iron. At the Mond Nickel Company, no assays of the roasted ore are made, as it is so variable in composition and difficult to obtain representative material, and one tenth is added to the assays of the raw ore, to enable the furnace manager to make up a charge for smelting.

Average of Copper Cliff roasted ore in 1902.

No assays made of Victoria mines roasted ore.

When an abundance of ore fines is in stock, over and above the usual requirements for covering and finishing the heaps, the excess is

Ore fines used to make bed for roast heaps.

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1. Jour. Can. Min. Inst. Vol. V., 1902, p. 544.

generally used to cover the ground on which the roast heap is to be built, to a depth of about six inches. The material is thus 'caked' together, in the roasting, and after having served for several roastings, is broken up and used as coarse ore, as it has only enjoyed an incipient oxidation. These roast piles are built up as follows: the place selected, may or may not be covered with the 'fines', as already mentioned, as occasion demands. Sticks of cordwood, of nearly uniform size, should be placed side by side, across both sides and ends of the rectangular area. The whole interior of this may be filled in with old stumps, roots, ties or cordwood, as material comes to hand, but, in such a way, as to form a level and solid bed, on which the ore is to rest. Over this, is placed small wood and chips, to fill up all the larger interstices, care being taken to provide small canals, filled with kindlings, at intervals of 8 to 10 feet, leading from the outer air to the center of the heap. As first practised, these canals connected with 'chimneys', along the centre which were specially designed to rapidly and certainly kindle the whole heap. These chimneys were usually built of four sticks or old boards, so fixed together as to leave an opening, communicating below with the draught passages. Five or six such chimneys sufficed for each pile, and they were made to project two feet above the upper surface of the heap, so that no pieces of ore could fall into the flue opening. Such precautions, to insure certain kindling, are, however, not needed, and the canals are amply sufficient for this purpose; besides, it was found that they induced undue local heating in their immediate vicinity, thus tending to incipient fusing or matting of the ore, which is to be specially guarded against. The bed of cordwood varies from 9 to 18 inches in depth, according to the size of the pile. This bed of fuel being completed, the coarse ore to the extent of about 65 per cent of the whole heap, is transferred by wheel barrows, from the cars, over a narrow and roughly constructed trestle platform, running the whole length of the heap. This plan is sometimes adopted by the Mond Nickel Company, at the Victoria mines, although, in some instances, the tram cars are deflected, by means of a spur or branch line, from the aerial tramway, running over the roast beds. The car is then lowered, and the ore dumped directly at any place desired. The medium sized ore or 'ragging', about the size of nut coal, is then carefully spread over the coarse ore, and lastly, the whole heap is covered up with fines, till a height of from 6 to 18 feet is reached, according to the size of the pile. The whole structure should then form a shapely rectangular pile, with sharp corners, and as steeply sloping sides as the ore will naturally lie on without rolling (about 45°).

Method of building roast heaps.

Disposition of fuel.

Chimneys at first used to help kindle the pile.

Number and method of building chimneys.

Canals are sufficient for draught purposes.

Incipient fusion to be guarded against.

Use of temporary trestles in building heaps.

Disposition of coarse, medium and fine ore.

The heap is now finished, and only those openings, connecting with the canals around the base of the pile are left exposed. Kindlings or cotton waste, saturated with oil, are applied to these openings, and these are simultaneously ignited. These openings are themselves covered over with 'fines', as soon as the cordwood is burning freely. In spite of this ample covering, the whole of this fuel, as stated by Mr. James McArthur, (1) is burned out in about 60 hours after lighting up. 'A complete oxidizing roasting process then begins, and continues until the end, namely, until the sulphur contents are so far reduced and burned off, that there is not sufficient left to promote further combustion. The remaining portion of the sulphur (6 to 8 per cent) is enclosed and sealed up in non-porous portions of ore or matte, the semi-fused covering of which would require to be re-broken, in order to expose fresh faces under heat and thus liberate the remaining sulphur. This could only be done by turning over and re-roasting the ore, after the first roast was finished, but it is not at all necessary, as the remaining sulphur is essential in the smelting of the ore, in order to produce a clean slag'. About twelve hours after firing, the whole heap should be pouring forth dense pale yellow fumes of sulphurous acid. Great attention is paid to the pile for the first few days, to prevent excessive local heating, which frequently causes partial fusion of the ore, this tending to prevent successful roasting. The heap is carefully and systematically watched day and night, and all holes or fissures, caused chiefly by settlement due to the burning out of the fuel, are at once covered with 'fines' of raw ore. After the first few days are over, the pile may be left to itself, until cold enough to remove to the storage bins or furnace. After the period of roasting is over, and the pile is cold enough to be handled, the outer covering of partially roasted ore is first removed. This is more abundant along the sides and base, and the precaution is sometimes taken to cover up these portions of the pile, with old iron sheeting, which materially assists in preserving the heat, thus aiding the roasting. The longer the period of roasting, the less the matting, and of course the larger the heap, the smaller quantity of the outside covering or margin is left only partially roasted. When this outer covering is removed to be re-roasted, the remainder af the heap is conveyed in wheel-barrows a few yards, in one case, to a sunken railroad, which runs alongside of the roast yards. At the Mond Nickel Company, it is loaded into cars, which are hauled up an inclined tramway, to an elevated series of storage bins at the roast yard, from whence it is loaded, as required, into the aerial tramcars, and thus conveyed to the smelter.

Igniting the roast heap.

Roasting is an oxidizing process.

Only from 6 to 8 % of sulphur remains.

Remaining sulphur essential to produce a clean slag.

Great attention given to roast heap, after firing, for first few days.

Outer covering first removed.

Different methods of handling roasted ore.

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1. Ann. Report, Bur. of Mines, Ont., 1903, p. 300.

Appearance of roasted ore.

The ore, when roasted, is aggregated together, in large clinker-like masses. These are loosened, and broken up into suitable pieces for smelting, usually by pick and shovel, but often the assistance of explosives are needed to help in the removal. This roasted ore is loaded on large side-dumping cars, and hauled by locomotives to the stock bins at the furnaces. An experienced workman, knows the difference in the quality of roasted ores at sight, and is able to mix them roughly, as they are loaded into the cars at the heaps, to be taken to the smelter and dumped into separate bins. Here it is sampled, and again mixed by the furnace men, and made into smelting charges and fed into the furnaces.

Removal of ore to stock bins.

SMELTING.

Smelting in Sudbury district.

The copper nickel ores of the Sudbury District are, at present, (June, 1904,) being treated by only one corporation, the Canadian Copper Company, but during the progress of our work in 1901 and 1902, both the Mond Nickel Company and the Lake Superior Power Company were also conducting smelting operations. The Mond Company produced both the blast furnace or standard matte, and the bessemer or converter matte, while the last mentioned corporation restricted their refining process to obtaining the lower grade or blast furnace matte. The smelter of the Lake Superior Power Company, situated at the Gertrude mines, was completed early in June, 1902, and for some time was treating from 100 to 160 tons of ore daily. The matte, resulting from these operations, steadily accumulated at the works, until the suspension of all operations of this concern in 1903, and, during this period about 2,000 tons of the standard matte were produced. This matte is stated to have contained 29 per cent of nickel and copper combined, the proportion of the nickel to the copper being as 2 to 1. It was proposed to further refine this product at a converter plant, being erected at Sault Ste. Marie, or to ship it elsewhere to be refined. In addition, about 20 tons of ore, daily, out of a total production of 200 tons, were picked out as free as possible from chalcopyrite, which quantity was laid aside, to be shipped to Sault Ste. Marie, for the manufacture of ferro-nickel.

Production of matte by Lake Superior Power Co.

Ore selected for manufacture of ferro-nickel.

Smelting at Murray mine.

From 1889 to 1893, the Murray mine conducted rather extensive smelting operations, making both standard and bessemer matte. The average of the lower grade product was 8·5 per cent of nickel and 4 per cent of copper, while Walker's analysis of the latter, showed it to contain 48·82 per cent of nickel and cobalt and 25·92 per cent of copper. The Dominion Mineral Company, during the same period, produced only standard or blast furnace matte, containing from 18 to 20 per cent of

Smelting at Blezard mine.

copper and 24 to 26 per cent of nickel. About 1893, and later in 1896 and 1898, the Drury Nickel Company and the same corporation reorganized under the name of the Trill Mining Company, smelted and sold about 420 tons of blast furnace matte. During the early '90's, the Canadian Copper Company produced a considerable amount of high grade matte by the bessemer process, but the refiners seeming to prefer the standard or blast furnace matte, the manufacture of this product was abandoned, and the bessemer plant, consisting of a cupola, and 3 converters, located at the East Smelter, has been left idle for the greater part of the time since. In the fall of 1900, the plant of the Ontario Smelting Works was installed by the Orford Copper Company, an organization closely related to the Canadian Copper Company, both of which, in April, 1902, were included in the amalgamation of these and kindred corporations, under the name of the International Nickel Company. These works were designed to further refine the low grade or blast furnace matte of the Canadian Copper Company.

Drury Nickel Co.

Bessemer matte produced by Canadian Copper Co.

Erection of Ontario Smelting Works.

Before the erection of the new smelter, which will be described and figured later, the Canadian Copper Company had smelting plants installed in two separate buildings, known respectively as the East and West Smelters. The processes at the two smelters were alike, and they differed only in the number of their blast furnaces. At the West Smelter there were eight, and at the East Smelter five blast fuanaces, in addition to the bessemer plant. Lately, the East Smelter has been dismantled, and in a short time it is stated to be the intention of the Company to pull down the West Smelter also, and concentrate all refining operations under one roof. At the time of writing, no smelting is carried on at Copper Cliff, but the Company have leased the Mond Smelter at Victoria Mines, for a period of six months, this lease expiring about the 1st of August next, and all refining operations going on at present are carried on at this place.

Equipment at the East and West smelters at Copper Cliff.

Canadian Copper Co's. lease of Victoria Mines Smelter.

The smelting or blast furnaces have the form of a flattened ellipse, are 9 feet in height to the charging door, and measure 9 feet by 5 feet at the top, and 8 feet 5 inches by 4 feet 4 inches at the tuyeres, of which there are 25 (2 inch), arranged in two rows. They are made of rolled steel, with a water space of two inches, between the outer and inner plates, and have for a bottom a cast iron plate, 1¾ inches thick, protected by fire-brick, the whole supported by four strong cast iron legs. A light dome of plate steel, brick-lined at the top and sides, covers the furnace, and in one side of this dome, on a level with the ore bins, is the feed door. The furnace gases pass to the stacks, (one to each pair of furnaces), through brick chambers, with trough-shaped sheet

Description of blast furnace.

iron bottoms. Here the flue dust, having an opportunity to be precipitated, is taken periodically from these chambers and added to the blast furnace charges. The smelters are situated at or near the ground level, and ore, coke and flux are brought into the building on an elevated track, and dumped into the bins on the feed floor level. The well, forehearth or settling pot, is built of cast iron water-jackets in four sections, with a water space of six inches, and rests upon four wheels, for convenience of moving it whenever repairs are necessary, a second well standing ready to be put in its place. When the forehearth is in position, a square opening on one side, is fitted by fire-clay, to a corresponding opening in the furnace, and the molten slag and matte flow into the forehearth, when the furnace is in blast. The feeding of the furnace is continued, at frequent and stated intervals, and as the molten mass gathers at the base of the furnace, it flows through the discharge hole, into the forehearth, where the heavier or metallic portion (matte), sinks to the bottom, while the lighter slag rises to the surface, to flow out in a continuous stream from a water cooled, phosphor-bronze slag spout, to a McArthur granulating trough, where it comes in quiet contact with a stream of water, that has already done duty in the water-jackets of the furnace, and flowing in the same direction as the stream of molten slag. This granulated slag is carried by the water, which gradually filters away into the dump or into the slag wells, out of which the slag is elevated, by means of a bucket elevator, into high waste heaps. From these immense dumps, road makers, and especially the Canadian Pacific and Manitoulin and North Shore railways, help themselves, loading this slag on cars, by means of steam shovels, for use as ballast, for which it is excellently adapted. It is much heavier than ordinary ballast, and does not retain water, and, therefore, is not so liable to wash-outs, or to freeze in winter and heave up the tracks, as does the ordinary sandy or silt ballast often used in the district.

Location of blast furnaces.

Description of forehearth.

Matte or metallic portion sinks to the bottom.

Use of McArthur granulating trough.

Disposition of granulated slag.

Use of granulated slag for ballast and roads.

The matte is drawn off periodically, the tap-hole for this purpose being situated at a lower level, which is opened with a pointed iron rod, and afterwards closed with a plug of fire-clay. This process is usually attended with a display of fireworks, but, as the men engaged at it become very expert, the stream of liquid matte is very quickly and effectively stopped. The matte is then allowed to remain in the cast iron pots or moulds, into which it has been tapped, until cool, when it is dumped out, broken by means of sledge-hammers, weighed, loaded on cars, and shipped to the Ontario Smelting Works for further treatment.

Tapping of matte.

Matte is allowed to settle in pots.

The blast is furnished by No. 7 Connersville blowers, discharging 67 cubic feet of air blast per revolution, and making from 90 to 130 revolutions per minute, each blower being driven by an engine of 50 H. P. The blast is delivered at the tuyeres at a pressure of about fourteen to sixteen ounces per square inch.

Use and strength of blast.

The roasted ore, with which the furnace is principally charged, is a mixture of oxides, sulphates and sulphides of nickel, copper and iron, together with a certain amount of the basic silicate of the gangue. The process of smelting is very economical, the ore furnishing in itself the exact ingredients for fluxing. By the smelting of the ore, with a small quantity of quartz, in the blast furnace, using from 15 to 17 per cent of Connellsville coke, the iron is chiefly reduced to ferrous oxide and forms a slag with the gangue and quartz.

Description of roasted ore.

Proportion of coke used.

Under I and II, are analyses of this slag by Mr. Donald Locke, late assayer of this Department. Under III, is an average analysis, published by M. John Herdt, (1) while under IV, is an analysis by Mr. J. W. Bain. (2).

Analyses of blast furnace slag.

	I	II	III	IV
Silica	34·16	32·58	38·00	26·67
Ferrous oxide	41·24	44·37	43·00	50·82
Ferrous sulphide	...	.....	.....	3·52
Lime	8·23	6·62	4·50	3·38
Magnesia	3·44	2·77	2·00	2·95
Copper	0·25	0·13	0·40	0·20
Nickel	0·23	0·23	0·45	0·10
Alumina	9·03	10·41	10·00	12·88
Sulphur	0·91	.....	.....	.....
Totals	97·49	97·11	100·85	100·52

The nickel and copper, and some of the iron, unite with the sulphur to form a matte. Under I and II, are analyses of this blast furnace or standard matte, the results obtained by Mr. Donald Locke, in November, 1902; under III, is an analysis, by Mr. J. W Bain, (1900); under IV, is the mean of two analyses of matte, which were made by Mr. F. L. Sperry, on the 22nd February, and the 2nd of March, 1889. Under V, is the copper and nickel determination for this matte, in February, 1891, while under VI, are determinations for these same metals, by Mr. L. P. Silver (1902).

Authorities for analyses.

Analyses of blast furnace matte.

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(1) "Les Mines de Nickel du District de Sudbury (Ontario)." Rep. Cham. de Commerce, Montreal, 1892, p. 39.

(2) Ann. Rep. Bur. of Mines, Ont., 1900, p. 217.

	I	II	III	IV	V	VI
Copper	14·69	14·53	19·87	26·910	17.24	20.35
Nickel	28·17	26·34	16·75	14·140	21·44	16·48
Iron	31·89	34·15	43·90	31·235		
Sulphur	24·96	24.93	18·72	26·950		
Cobalt	.....	.....	0·63	0·235		
Slag	.....	.....	0·05	0·935		
Totals	99·71	99·85	99·92	100·405		

Average daily charge and production of blast furnace.

Each furnace, of which there were 13 installed, puts through about 130 tons every 24 hours, the total capacity being about 1800 tons per day.

Mr. Donald Locke gives the following average for a day's work of a furnace. In a day of 23 hours, using 12 oz. blast pressure, there were smelted 264,000 lbs. of roasted ore, assaying :—

Copper	1·43	per cent.
Nickel	2 56	"
Silica	26·00	"
Sulphur	5 57	"

Nickel and copper contents of matte produced.

To this was added 3,600 lbs. of quartz, with 98 per cent of silica, using 45,300 lbs. coke (17 per cent). There were produced 26,318 lbs. of matte, containing :—

Copper	11·90	per cent.
Nickel	22·10	"

Composition of slag.

and 207,425 lbs. of slag, containing :—

Copper	0·27	per cent.
Nickel	0·40	"
Silica	32·00	"
Iron	40·00	"

Description of extraordinary run.

An extraordinarily good run was as follows :—With a 16 oz. blast, there were smelted in 24 hours :—

Ore	510,000	lbs.
Quartz	2,250	"
Using coke	87,200	"

There were produced :—

Matte	44,231	lbs.
Slag	439,233	"

The furnace gases pass to the stacks (one to each pair of furnaces), through brick chambers, with trough-shaped sheet iron bottoms. Here the flue dust, having an opportunity to be precipitated, is taken periodically from these chambers, and added to the blast furnace charges. Four samples, assayed by Mr. Locke, in 1902, resulted as follows :—

Formation of flue dust.

Nickel and copper contents of flue dust.

	I.	II.	III.	IV.
Copper..........	1·45	1·49	1·55	1·39
Nickel...........	3·28	3·84	3·79	3·62

An assay of a typical sample, by Mr. L. P. Silver, (¹) gave copper 4. 25 per cent and nickel 3·37 per cent.

In the roasting of the ore, a large proportion is badly roasted, or, owing to the heat in the pile being too intense, the ore melts to matte, and is not roasted at all. This should be re-roasted, and is so, to a certain extent, but when large orders are on hand, this unroasted and partly roasted ore, is smelted in the blast furnace, and the resulting low grade matte is 'split,' that is, poured out on the ground in layers of about half an inch in thickness, and broken up. Two assays of this 'spilt' matte, collected in November, 1902, gave Mr. Locke the following results :—

Production of 'spilt' matte.

Composition of 'spilt' matte in Nov. 1902.

Nickel	2·30	per cent.	3·43	per cent.
Copper......	3·26	"	3·56	"
Iron........	63·08	"	61·18	"

This matte usually contains from 7 to 15 per cent of the metals and a typical sample, analyzed by Mr. L. P. Silver, (op. cit.), contained, nickel 6·01 per cent and copper 7·45 per cent.

Other assays of 'spilt' matte.

This 'spilt matte' is broken up and taken to the roast-yard, where it is roasted in small heaps (about 200 tons). After the necessary oxidation, the roasting usually lasting about 30 days, it is re-smelted being added to the blast furnace charge, in place of some of the ore, the matte thus produced being thereby much richer in metallic contents.

Roasting of 'spilt' matte.

Previous to the installation of the plant at the Ontario Smelting Works, the Canadian Copper Company still further refined their own blast furnace or standard matte, by the 'Bessemer Process.' In these earlier years, about 1893, this was done on rather an extensive scale, but during the later '90's, there was no very constant or large demand for this higher grade of matte, and this method of concentration was only practised as occasion demanded. The converter used was of the Manhés type, with a capacity of one and a half tons, with a new lining, and three tons with an old lining.

Bessemerizing by Canadian Copper Co.

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(1) Jour. Can. Min. Inst., Vol. V, 1902, p. 546.

Dimensions of converters.

The process is very similar to that followed in bessemerizing iron. The Manhès converters are cylindrical shaped vessels, with convex ends measuring usually about eight feet in length, with a diameter of about four feet. They are made of boiler plate, and lined with a thick layer of clay mixed with quartz.

Employment of quartz from Bruce Mines.

Silica used now comes from near Kelley lake.

In the first years, much of the quartz used, and especially at the Murray mine was obtained from the Bruce Mines, where great quantities of 'skimpings' exist, resulting from the jigging of the ore from that mine during its operation in past years. This material consists of the crushed quartzose gangue, cleaned of all but a small proportion of the sulphides of copper, constituting the ore. It carries but a small proportion of felspar. The silica, now to be used, is obtained from a large vein of massive quartz, situated on the high range of norite hills near the shores of Kelley lake, a little over a mile south of the large new smelter.

Description of converter.

The converter rests, with its axis horizontal, on a carriage running on a track. It is provided, on its upper side, with a mouth or throat through which it can be charged. The dimensions are: length 7 feet, 3 inches; diameter 5 feet, 8 inches. The blast is driven through the charge from two parallel series of small tuyere holes, piercing the lining, along either side, below and along the length of the vessel. Opposite each of these tuyere holes, corresponding holes are pierced through the tubes, which run along the outside of the converter, to supply them with blast. These holes are closed with wooden plugs, removable to admit an iron bar, which, being poked through them successively during the process of blowing, keeps the tuyeres clear and the charge stirred.

Motions of converter.

A gearing enables the converter to be rotated on the car about its horizontal axis, and the throat having been thus lowered, a charge of low grade matte, from the well or forehearth of the cupola, is run into it by means of a trough. It is then rotated back, till the mouth is again vertical, and run around underneath a large hood, connected with a stack, in another part of the smelter house where it is connected with the blower.

Gradual application of pressure.

At first, a pressure, starting at 5 lbs. of an air blast, is blown through the mass of metal, when a violent agitation takes place, and on raising the pressure to 7 lbs., white fumes appear. As there are none of the usual flame reactions, the point at which to stop the blast, after the iron has been removed, and before the nickel has also begun to slag, in undue amount, requires special experience and judgment. The end of the operation is determined mainly, by a perceptible decrease in the temperature of the mass, as shown by the flame, but also of the fragments splashed or blown out of the converter, as well as by the size and appearance of the particles, which gradually become larger and more frothy, at the last issuing in pieces about the size of a man's hand. The duration of the blowing operation depends on the size of the charge, and the displacement of the converter spaces for the silicious lining is gradually appropriated by the iron in the charge. Each charge is, therefore, greater than the preceding one, until the sixth or seventh charge is blown, when the converter is laid to one side for relining. As a result of this, the continuance of the blast generally varies from 20 to 80 minutes, averaging about 50 minutes.

Criteria for judging when end of process is reached.

Charge of converter dependent on use.

During this bessemerizing process, the iron is almost entirely removed, the sulphur lowered to from 10 to 15 per cent, and the copper and nickel combined to from 80 to 85 per cent. The iron unites with the silicious lining, to form a very fluid slag which is spilled off the top. The amount of nickel, lost by oxidation, is very trifling, cobalt is perfectly scorified, zinc, arsenic and antimony are completely driven off, while bismuth, silver, gold and platinum are entirely concentrated in this matte.

Objects of bessemerizing.

The following are analyses of this bessemer matte:—

Analyses of bessemer matte.

	I.	II.	III.	IV.	V.	VI.
Nickel... Cobalt...	39·96	40·93	31·35	41·18	39·64	48·82
Copper....	43·36	45·71	48·86	44·87	42·75	25·92
Iron......	0·30	0·40	0 81	0·94	1·03	2·94
Sulphur....	13·76	.....	.....	11·62	14·05	22·50
Gold....	0·1 to 0·2 oz.	.....	.....	0·3 oz.	0·75 oz.	·000075
Silver......	7 oz.	.. ..	.....	5·1 oz.	5·30 oz.	·001775
Platinum .	0·25 oz.	.....	.....	....	0·50	·000430
Iridium....	....	.....	.....	....	....	·000056
Osmium....	....	.....	.....	...	....	·000057
Rhodium ..	....	.. ..	....	....	....	Trace.
Palladium .	0·25 oz.	.....	.....	.. .	...	Trace.

Explanations.—Analysis I, is by Titus Ulké and is styled 'a fair average analysis of the Canadian Copper Company's bessemer matte.' (Min. Industry, Vol. III., 1890, p. 460); II. and III., are by Roberts-Austen, (Min. Proc. Inst. Civ. Eng., Vol. CXXXV, p. 30); IV., is an analysis, by J. W. Bain, (Ann. Rep. Bur. of Mines, Ont., 1900, p. 218); V., is an analysis by L. P. Silver, (Jour. Can. Min. Inst., Vol. V, 1902, p. 534); VI., an analysis by Dr. T. L. Walker, of the besse-

Authorities for analyses.

Comparison of Norway and Sudbury mattes in regard to precious metals.

mer matte, from the Murray mine, (Amer. Jour. Sc., Vol. I., 4th Series, 1896, p. 112; also Ann. Rep. Bur. of Mines, Ont., 1903, pp. 283-284).

Under Norway, on a preceding page, analyses of similar concentrated matte, obtained from the Norwegian pyrrhotite, are also quoted. These show the presence also of gold, silver and platinum in appreciable quantities. Speaking roughly, the silver is only from $\frac{1}{2}$ to $\frac{2}{3}$ of that present in the Sudbury matte, the gold about the same as that in the Murray mine matte, which is only about $\frac{1}{4}$ of that present in the mattes from the Copper Cliff and Victoria mines, while the metals of the platinum group occur in about half the amount of that present in the Murray mine, this matte itself only containing less than half that usually present in the mattes produced from the Copper Cliff and Victoria mines.

Relative proportions of precious metals in Norwegian mattes.

Prof. Vogt, also gives the interesting information, that the proportion of these metals present in the Norwegian ores and mattes, is one part of gold to 20 of silver, one of platinum to 30 of silver, one of silver to 5,000 of nickel and one of platinum to 150,000 of nickel.

Analyses of bessemer slags.

The following are analyses of the converter or bassemer slag. All converter slags are returned to the furnaces for re-smelting, as they are so high in nickel.

	I.	II.	III.
Ferrous Iron	66·6	67·1	67·6
Silica....	28·5	27·9	27·5
Nickel	1·9	1·6	1·4
Copper..................	1·1	0·8	1·2
Sulphur.......	0·5	0·4	0·5

Authorities for analyses.

I and II., are analyses by Edwards, (Eng. & Min. Jour., May 2nd, 1896); III., is an analysis by L. P. Silver, (Jour. Can. Min. Inst., Vol. V., 1902, p. 549).

Canadian Copper Co's mattes refined at Ontario Smelting Works from 1900.

From about the beginning of November, 1900, until the destruction of the plant early in the spring of 1904, the blast furnace matte produced by the Canadian Copper Company, was further refined at the Ontario Smelting Works, built and operated by the Orford Copper Company, at Copper Cliff. This company was a closely allied corporation, and both were consolidated in 1902, under the management of the Canadian Copper Company, itself a subsidiary organization of the International Nickel Company.

Preparation of matte at Ontario Smelting Works.

The standard matte is brought from the Canadian Copper Company's works on cars, and put through a Blake crusher. It passes from that directly into a Krupp ball mill, where it is reduced to a fine powder. From the ball mill, it runs on a belt conveyer, which raises it to a storage bin, and from this storage bin, it is conveyed still further, as required, on belt conveyers, to the feed hoppers of the roasting furnace.

Description of equipment at Ontario Smelting Works.

The matte is roasted in two Brown, straight-line, automatic reverberatory calciners, each with a hearth area of 140 feet by 10 feet. Later, these furnaces were enlarged to 200 feet, and a third one of similar dimensions was also built. One furnace has six sets of ploughs, and the other seven. The ploughs make one complete trip in 6½ minutes. The plough carriage, on passing the automatic feeder, causes a certain amount of the powdered matte to fall into the furnace. Each furnace puts through 45 tons of matte in 24 hours, and reduces the sulphur from 25 to 30 per cent down to 5 to 8 per cent, using 4½ cords of wood per furnace per day.

Capacity of reverberatory calciners.

The roasted matte is discharged from the furnaces, into the trough of a screw conveyer, which takes it to the feeding floor of the blast furnace.

Dimensions of 'Orford' furnace.

The furnaces are of brick usually known as the 'Orford' furnace, cooled in the region of the tuyeres, by water circulating in pipes, embedded in the brickwork. The furnace measures 50 inches by 128 inches at the tuyeres, of which there are seven.

Blast.

The blast is furnished by two No. 9 Sturtevant, centrifugal blowers. The furnaces are fed by hand, the charge consisting of roasted matte, fed in powder form, with quartz tailings and some roasted ore.

Formation of large amount of flue dust.

Owing to the large amount of fines in the charge, great quantities of flue dust are formed—40 tons a week being a usual figure, and often as high as 80 tons a week being produced. This flue dust, assaying about 11 per cent of copper, and 18 per cent of nickel, is put through the furnace again.

Description of 'Orford' forehearth.

The matte and slag flow from the furnace continuously, into an Orford siphon-tap forehearth. This consists of a rectangular box about 4 feet long, 2 feet 6 inches wide and 18 inches high, formed of cast iron plates strongly bolted together at the corners and lined with a 6-inch brick wall. It is divided into two parts, in the ratio of about 2 to 3, by a 9-inch division wall, with a slot on the level of the floor of the forehearth, through which the matte can flow from the larger to the smaller compartment. The whole forehearth is supported on wheels. The matte and slag flow from the furnace into the larger com-

Settlement of matte.

partment, the forehearth fills, the slag, being lighter, floats, and only the matte is able to find its way to the smaller compartment, through the slot at the bottom of the division wall.

Discharge of matte and slag.

When the forehearth is full, matte and slag are discharged in separate and continuous streams, the former being received in cast iron pots. This refined product is shipped to the Orford Copper Company, New York, for the separation of copper and nickel. Two samples of this high grade matte, assayed by Mr. Donald Locke, contained as follows :—

Analyses of Ontario Smelting Works matte.

Nickel	41·58	40·37
Cobalt	0·71	0·78
Copper	24·99	24·95
Iron	9·82	9·64
Silver		2·50 oz. per ton.
Gold	0·15 oz. per ton.	0·10 oz. per ton.
Platinum	0·50 " "	0·44 " "

Analyses of Ontario Smelting Works slag.

Two samples of the slag collected at the same time, analyzed by Mr. Donald Locke, gave the following results :—

Silica	31·03	26·62
Ferrous oxide	64·31	66·72
Lime	0·22	0·24
Magnesia	0·08	0·09
Nickel	2·57	2·68
Copper	0·56	0·77
Alumina	0·54	0·54
Sulphur	0·49	0·30
Totals	99·80	97·96

Slag is re-smelted.

This slag is taken to the Canadian Copper Company's works, and put through the blast furnace, to recover the metal contents, which are too high to be neglected.

PYRITIC SMELTING.

Pyritic smelting in Canada.

Mr. James McArthur is authority for the following statement: (1) 'Cold blast pyritic smelting of sulphide ores has been carried on in Canada, off and on, and for long periods at a time, since 1879; not as an experiment but as a process. Thousands of tons of copper sulphide fines have been smelted with cold blast, and later on in recent years at Copper Cliff with cold and also with very moderately hot blast (the latter about 400°F.), making in these recent operations some 18,000 to 20,000 tons of matte product. The coke consumption was about 5 per cent for both temperatures of the blast, the grade of matte product being almost identical. With a blast temperature sufficiently high,—not less than 1200° F.—to counteract gumming at tuyeres, the sulphur contents of the ore, which should be the only fuel used apart from a small percentage of the iron, can be kept in ignition, and with a higher pressure of the blast we should get sufficiently rapid oxidation action, even in a large and fast smelting furnace, to produce a direct 30 per-cent matte, or over seven into one, from a raw 4 per cent ore as it comes from the mines, because if we can dispense with all carbonaceous fuel in first smelting and can use the sulphur contents of charge in its stead, we stop all reducing action, and in lieu thereof introduce a complete oxidizing action, oxidizing the iron and consuming the sulphur in the operation.'

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(1) Ann. Rep. Bur. of Mines Ont., 1903, pp. 302 & 303.

Description of process.

Average metallic contents of matte.

Just to what extent green ore will be employed, in place of roasted ore, under the new conditions which will obtain at the new smelter, which is about to be described, and where the pressure will be 40 ozs. instead of 14 ozs., cannot be foretold, but it is expected that a very large amount of raw ore will be added to the furnace charge.

Extent of pyritic smelting to be employed, uncertain.

The drawings, accompanying this bulletin, are plan and sectional elevations of a 1000-ton smelter designed by the Engineering Company of New York. (¹) These were submitted to the Canadian Copper Company, who, after their approval and adoption, proceeded to instal this new smelting and power plant, in which are assembled the latest and best improvements and conveniences for every part of the work. It is confidently expected that this smelter will be in operation early in July (1904). (²)

Preparation of plans for smelter for Canadian Copper Co.

In the erection of this smelter, there were several objects that had to be borne in mind, among them the cheap handling of a large tonnage of ore, the storage during the winter months of materials, such as coke and coal, which can be received by boat during summer; the elimination of all needless manual labor, and the thorough efficiency of the power department. The plant was designed to be erected on two levels; the large amount of slag produced had to be taken into consideration and the disposition of this slag was an important factor

Objects to be attained in building new smelter.

Disposition of slag.

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(1) The blocks for the drawings reproduced in this report were kindly loaned by the *Engineering and Mining Journal* of New York.

(2) Eng. Min. Jour. Vol. LXXVI. Dec. 31st, pp. 1003-1009.

in determining the site. The plant, as it now stands, was built along the face of a cliff, on the northern side of the flat, on which the town of Copper Cliff stands.

Description and location of storage bins.

On the upper edge of the cliff, a system of bins has been constructed for storage purposes. The smelter building proper, is situated parallel to these bins, with the power-house at the northeastern end. A trestle was built on the grade level of the bottom of the bins, which is also the grade level of the charging floor connecting the charging flooor with the bins and also with the power-house, making a circular track. running on both sides of the furnaces, and passing the coal chute in front of the power-house. After roasting, the ore is loaded into 50-ton hopper-bottom cars, and drawn up to the top of the bins by 70-ton locomotives. The track leading to the trestle is on an easy grade all the way, and is also connected with the main line, leading to the Canadian Pacific railway.

Removal of roasted ore.

Disposition of various products.

All ore, flux, coke, coal, etc., is handled on these tracks, and dumped directly into the bins. Running on the circular track underneath the bins, and into the smelter building, and past the power-house, is an electric railroad, with side dumping cars drawn by electric locomotives. The ore, coke, etc. is loaded into these cars, and weighed on the end of the trestle. The furnace charge is dumped direct into the furnaces, and the coal into the pockets next the power-house.

Description of sectional elevations. Dimension of buildings.

As shown by the sectional elevations, the site consists of two levels, with a difference of 35 feet in elevation. The upper level is the same elevation as the feed-floor, and is occupied by a double-track pocket trestle, 35 x 35 x 600 feet.

On the lower level, are located the power-house, 156 by 102 feet; the blast furnace building, 84 by 283 feet; the foundation for the trestle carrying the electric tramway, connecting the storage pockets with the feed-floor; the coal-bins of the boiler room; the dust-chamber, 16 feet wide, 18 feet high and 444 feet long; the stack, 15 feet inside diameter, 210 feet high; together with the necessary slag tracks, sunken tracks for loading metal for shipment, tracks to store house, etc.

Details of equipment of power-house.

The power-house is equipped with two Nordberg Manufacturing Company's horizontal, cross-compound, condensing, blowing engines, with steam cylinders, 13 inches and 24 inches by 42 inches and air cylinders 57 inches and 57 inches by 42 inches. When operating, under usual working conditions, these engines will deliver 20,000 cu. ft. of free air per minute, against a pressure of 40 ozs., for use in the blast furnaces. One Nordberg Manufacturing Company's horizontal cross-compound, condensing, blowing engine, with steam cylinders 15 inches and 30 inches by 42 inches and air cylinders 40 inches and 40 inches by 42 inches, will deliver 10,000 cubic feet of free air per minute, against a pressure of 15 lbs., for use in the converters. Two 13 in. and 26 in. by 20 in. horizontal, compound, condensing engines, built by the Robb Engineering Company, to each of which is directly connected one 200 kw. 600-volt, 3-phase alternating current generator, built by the Canadian General Electric Company, each generator having its own exciter of 11 kw. capacity, belt driven from generator shaft. The electrical energy thus generated, is used for hoisting in and pumping at the mines, operating the electric tramway for charging cars, turning the converters, and operating the travelling crane in the furnace building. The station is also equipped with one 25 kw. motor driven generator set, for furnishing direct current to the electric locomotives. A travelling crane of ample capacity is installed in the engine-room for handling all this apparatus. A gravity oiling and oil filtration system is installed on all engines.

Electrical equipment.

In the boiler room, the present installation of boilers consists of four 400-H. P., 150-lb. pressure, horizontal water-tube boilers, built by the Aultman & Taylor Machinery Company, of Mansfield, Ohio, and space is provided for two more boilers of the same size. The boilers are equipped with Potter Super-heaters and Tread-Kill shaking grates. The ashes are removed from the boiler ash-pit by opening a grate in the bottom, which permits them to fall into a bucket resting on a small flat car, which runs on a track in the ash-tunnel under the boilers. The car is then run outside of the building and a hoist lifts the bucket and dumps the ashes into an ash-bin, from which it runs into cinder cars.

Description of plant in boiler house.

Coal is brought to the power plant by the electric locomotive train, above referred to, and dumped into bins built in the trestle along the west side of the building. Then it runs through coal chutes to one-half ton coal cars in the boiler room, from which cars it is shovelled into boiler furnaces.

Movement of coal.

The only available water for boiler use, contains considerable sulphuric acid and scale-forming elements, and, to eliminate these, the water is subjected to a chemical treatment and precipitation, in a water purifying system, built by the Industrial Water Company, of New York. In this way, the acid is neutralized, and the scale-forming material is removed, before the water enters the boilers. The condenser is of the elevated barometric shape, built by the Alberger Condenser Company, of New York.

Treatment of water before use in boilers.

Style of blast furnace used.

The blast furnace building contains two sectional, rectangular, water jacketted, Holthoff, copper blast furnaces, three stands for Holthoff converters; one 40-ton electric crane; the necessary matte-settlers, clay mills, silica and clay storage bins, etc. Room is provided for expansion.

Methods employed in movement of products.

In operation, the ore, coke and flux for the blast furnaces, silica and clay for lining the converters, and coal for the boilers, are delivered into the top of the trestle pockets, by standard-gauge cars—Ingoldsby drop-bottom in the case of the ore, and drawn from the bottom of the pockets into trains of six 2-ton, 36-in. gauge, side-dump, Koppel cars, which are hauled to the blast furnace, silica and clay storage bins, or coal bins, by 25 H. P. Canadian General Electric Company electric locomotives.

Disposition of slag and matte.

The slag and matte run from the blast furnace into 16-in. settlers, the slag overflowing into 30-ton Pollock cinder cars, which are hauled to the dump by standard gauge locomotives. The matte is tapped into 10-ton cast-steel ladles and taken to the converter by a 40-ton Case Manufacturing Company's electric crane. The same crane removes the converter shells for re-lining, and takes care of the converter slag and white metal, pouring them into moulds for return into the pocket trestle, or for shipment to the refinery. The coal bins at the boilers, and the silica and clay bins at the clay mills, are kept full by six-car train-loads of material.

Removal of flue dust.

The flue dust is drawn from the dust chamber into a standard gauge bottom-dump gondola, especially fitted for the service, and this car is hauled to the top of the pocket trestle on the upper level, and the dust drawn into a pocket fitted for the purpose, whence it is drawn to a briquetting machine, pressed into briquettes and added to the charge.

Operation of electric tramways.

The electric tramway consists of two parallel 36-in. gauge tracks, running under two lines of grates under the pocket trestle, then over suspension scales to opposite sides of the furnaces on the feed-floor level, passing over the top of the boiler room, coal bins and converter lining house, silica and clay bins. The two tracks have cross-over connections, but, under normal working conditions, each track carries a train entirely independent of the other.

Dimensions of blast furnaces.

The blast furnaces are 50 in. by 204 in. at the tuyeres; 14 feet 9 inches from centre of tuyeres to the feed-floor, and have, on each side, four lower jackets, each 51 in. wide and 8 feet 6 inches high, and two upper jackets, 8 feet 6 inches wide and 6 feet high. Each lower side-jacket carries four 6 in. tuyeres. Both ends of the furnace are made alike, so that either end can be used for removing matte and slag.

There is no brick work under the deck beams. The converters are 84 in. by 126 in., and are tilted by a train of gears and a worm, driven by the electric motor.

Size of converters.

The water for the plant is supplied by a 16-in. pipe, running from a dam, situated about 5,000 feet from the plant itself. The water is run by gravity into the jackets and when drawn out, is pumped into a tank above the smelting plant, for fire purposes, or into the reservoir, which is near the foot of the plant, and the hot water is also used in the boilers in order to economize at that point.

Water supply.

The Mond Nickel Company refine the ore from their own deposits at Victoria Mines, a station on the 'Sault branch' of the Canadian Pacific railway, 22 miles west of Sudbury. Their smelter, before the erection of the new one, now about completed, at Copper Cliff, was the most modern and best equipped in the district. It not only produces standard or blast furnace matte, but further bessemerizes this into a concentrated matte, containing about 80 per cent of nickel and copper, these two metals being present in about equal amounts, 18 per cent of sulphur, about 0·75 per cent of iron, and 0·25 per cent of silica. This is sent to England, to be treated there, by the Mond process, for copper and nickel. Difficulties, in connection with the operation of their refining at Clydach, Wales, have, for the time being, caused a suspension in their mining and metallurgical operations in the Sudbury District, while their smelter has been operated by the Canadian Copper Company under a six month's lease, which expires about August 1st next (1904). It is authoratively stated, however, that these difficulties have now been successfully overcome, and that their refinery, greatly enlarged and with all the necessary changes, is ready to go to work. It is confidently expected that immediately on the expiry of the Canadian Copper Company's lease, the smelter will again resume operations, under the former management, on even a larger scale than before. The North Star mine, on the Manitoulin and North Shore railway, is, at present, being developed under option by this company, under the direction of Mr. C. V. Corless, and the ore secured is shipped to Victoria Mines for treatment.

Location of Mond Nickel Co's smelter.

Modern equipment.

Average composition of bessemer matte.

Matte shipped to Wales for refining.

Lease of Mond Co's. smelter to Canadian Copper Co.

Expectation. that Mond Co. will resume operations.

Mining at North Star mine.

The roasting of the ore is carried on as at the Canadian Copper Company's works, The roasted ore is brought to the smelter, by means of an aerial teamway, from the roast yards, which are about one mile distant.

Roasted ore carried by aerial tramway.

The smelter is erected on a sloping hillside, and has three levels, those of the feed floor, the furnace floor and the converter floor. The roasted ore is brought into the smelter to a platform, above the third

Location and general description of smelter.

level, where the tubs are received by a boy, after having been automatically unhitched from the haulage rope. The boy runs the tubs to the bins, tips them and hitches them, again empty, to the outgoing rope. The ore bins are situated above and behind the feed floors, so that the roasted ore can easily be discharged, through chutes, into the dump cars on the feed floor.

No assays of roasted ore made.

Assays of the roasted ore are not made, owing to the difficulty of selecting samples, and without careful sampling widely different results are sure to be obtained. For the purpose of deciding the proper proportions of ore, to be included in the furnace charges, one-tenth is added to the assays of the raw ore. The averages of the daily assays of raw ore for July and September, 1902, made by Mr. T. M. Paris, chemist to the Mond Nickel Company, are given under I and II respectively, while, under III, is given an average of several months assays.

Average nickel and copper contents of ore from Victoria mine.

	I.	II.	III.
Nickel	2.67	3.21	3.05
Copper	2.81	2.41	3.05
Insoluble	17.20	13.90	17.01

Description and dimensions of blast furnace.

The ore is smelted in rectangular, steel, water-jacketed furnaces, 12 ft. high, 42 in. by 120 in. at the tuyeres, and increasing slightly towards the top. The two furnaces (only one runs at a time) have each 16 tuyeres, 8 on each side, a cast iron water-cooled tap jacket and Hixon slag spout. This consists of a coil of 1 in. piping, cast around with cast iron so as to form a channel some four feet long, through which the matte and slag flow continuously into the forehearth. The spout is fully described in Hixon's 'Lead and Copper Smelting,' pp. 28-30. One furnace puts through about 170 tons a day, made up (for example) as follows :—120 charges each containing :—

Character of average furnace charge.

	A.	B.
Flue dust	200 lbs.	
Tailings	200 "	250 lbs.
Converter slag	500 "	500 "
North Star ore	300 "	250 "
Roasted ore	1,600 "	1,800 "
Coke	300 "	300 "

Tailings from Bruce Mines.

The tailings are practically pure quartz, with a small percentage of copper, from the Bruce Mines.

Use of North Star ore.

The North Star ore (obtained from the North Star mine) is not roasted, and the quantity used is varied according to the amount of sulphur in the roasted ore. The charges are dumped directly from the dump-cars into the furnace, through the open top, alternate charges being fed to the sides, by means of a simple device, consisting of a wrought iron pipe, about 8 in. in diameter, through the length of the furnace opening, and let down about three feet into the furnace. On this the charge falls and is deflected towards the sides. The blast for each furnace is furnished by a No. 6 Green blower. The forehearth is of boiler iron, 10 feet in diameter, with 6 in. lining of fire clay and quartz. In this, the matte and the slag have every opportunity for a complete separation, and, owing to its large size, the converter foreman can always be assured of having sufficient matte ready for him, when he requires it. When the hearth fills, the slag spout is at first kept stopped up, so that the bath rises right to the top of the hearth, and a stiff slag crust forms, which is covered with a layer of non-conducting coke. This forms the hearth cover. After the formation of the cover, the slag spout is opened and the slag overflows, and is granulated by falling into a powerful stream of water, and is carried to the slag dump by means of a large cast iron pipe.

Simple device for charging furnace.

Use of blast.

Description and size of forehearth.

Formation and disposition of slag and matte.

Under I, is given the average of the blast furnace slag assays for September, 1902; II, is the average for several months in the same year, by Mr. T. M. Paris, of the Mond Nickel Company, while, under III, IV and V, are similar assays, by Mr. Donald Locke of this Department.

Average metallic contents of blast furnace slag.

	I.	II.	III.	IV.	V.
Nickel	0·30	0·34	0·31	0·25	0·28
Copper	0·36	0·35	0·33	0·28	0·29
Silica	31·20	31·31	30·50	32·00	30·70

The matte is tapped, periodically through the water-cooled tap-hole, flowing through sheet iron channels, lined with clay, into the converters, which are situated on the lowest level of the smelter. About 20 to 25 tons of matte are produced per day, by one furnace.

Removal and average production of matte.

Under I, is given the average of the metal contents of this blast furnace or standard matte for September, 1902. Under II, the average for several months, in the same year, by Mr. T. M. Paris, while III, IV and V, are assays, by Mr. Donald Locke, of this Department.

Average nickel and copper contents of blast furnace matte.

	I.	II.	III.	IV.	V.
Nickel	15·20	16·53	13·80	15·00	15·50
Copper	13·14	16·22	12·10	11·80	12·00

In the converter department, are 6 Leghorn converters, only one of which is in use at a time, the others being repaired, lined or dried.

Equipment of converter department.

The lining consists of a mixture of quartz and clay, the quartz being crushed and then ground in a Chilian mill, where it is also mixed with the clay and moistened.

Method of lining converters.

Preparing a converter for work.

In lining a converter, the bottom is first put in and tamped firm; a tapering iron tub is then placed in the converter, and round this the lining is firmly tamped. When the lining is completed to the top of the tub, the tuyere holes are punched, the tub lifted out, and the top of the converter put on. This is then lined, and the converter moved to where a blast pipe can be connected. A wood fire is lighted and the blast turned on. The fire is kept up until the converter is wanted. The converters are moved, from place to place, by means of a travelling electric crane, commanding the whole floor of the converter department.

Average converter charge.

Use and strength of blast.

The first charge of a newly lined converter is only about 1 ton, but as the lining is eaten away, the size of the charge increases, the average charge being about 2 tons. A lining lasts from 11 to 12 hours, about 6 charges being blown in this time. A blast of 10 lbs. pressure is employed.

Disposition of slag and matte.

During the blowing of a charge, the slag is twice poured off into slag pots, by tipping the converter, the blast being turned off during the pouring. The finished matte is poured into a clay-lined bucket, which is carried by the electric crane, and the matte tapped from it into flat, cast iron moulds.

Analysis of bessemer slag.

The following is an analysis of a clean converter slag, by Mr. Donald Locke, of this Department.

Silica	33·40
Ferrous oxide	46·50
Lime	0·93
Magnesia	0·08
Nickel	0·55
Copper	0·45
Alumina	4·60
Sulphur	1·17

Average metallic contents of bessemer slag.

The total amount of copper and nickel skimmed off, or poured from the matte during the converting, is, of course, much larger than this, as the last skimming contains much pasty, half fused substance, containing matte, and being higher in nickel than the clean slag. The average, therefore, of the converter slag would be considerably higher in nickel, averaging about 1·5 per cent of copper and from 1·5 to 2 per cent of nickel.

Analyses of bessemer matte.

The bessemer or converter matte contains as follows, according to two analyses, by Mr. Donald Locke, of this Department :

Nickel........	41·88	41·23
Cobalt	0·33	0·52
Copper........	37·37	37·83
Iron	1·07	0·77
Gold....	$\frac{1}{18}$ of an oz. to a ton of 2,000 lbs.	
Silver..........	4·87 oz.	" "
Platinum......	0·40 oz.	" "

Slag returned to blast furnace.

The slag is broken as soon as it sets, loaded into small cars, and raised to the feed floor, to be put through the blast furnace on an inclined elevator, on the west side of the smelter.

Removal and shipment of matte.

The matte, when cold, is crushed in a Blake crusher, and packed in barrels, to be sent to England, for further treatment.

Location of railways.

A railway track passes the lowest level of the smelter, to take away finished products, etc., and a track enters the upper level, to bring coke, raw ore, quartz, etc.

Equipment of engine house.

The engine house, situated to the west of the smelter, contains the Riedler blowing engine for the converter, the blowers for the blast furnaces, a pump to furnish the hydraulic power for turning the converters, two dynamos—one working by day and one by night—which supply light and power for the crane, for the two crushers—one for matte, the other for the quartz for the converters—for the Chilian mill, and for the aerial tramway. Power is furnished by 5 horizontal tubular boilers.

REFINING OF NICKEL.

Neglect of nickel by scientific men.

The subject of nickel has not, until quite recently, received from truly scientific men, that proper share of attention and inquiry which the known, desirable, physical properties of the metal demanded, these giving ample promise of its possible, wide, industrial application. Several reasons might be assigned, for this apparently unwarranted apathy in regard to such a hopeful field of inquiry, but, doubtless, the most important influence, related directly to the apparently limited distribution and supply of ores containing this metal, and the great, and for a long time, insuperable difficulties, encountered in all attempts at refining the ores, so as to obtain an absolutely pure and uniform product. From 1840 to 1860, the production of nickel was less than 200 tons annually, derived principally from the mines of Saxony and Hungary, with much smaller quantities from Sweden and Norway.

Early production of nickel.

Between the latter date, and the year 1876, the greatest proportion of the world's supply of nickel was obtained from the mines of Norway and Sweden, with much smaller quantities fron Saxony, Hungary and the United States. Careful examination of the occurrences of these nickel deposits, in the countries mentioned, indicated their probable exhaustion at no distant date, especially, if called upon to maintain a large and steady output. The prospecting undertaken, resulted in no new discoveries of a startling nature, and everything pointed to a comparatively limited supply and demand. This state of affairs continued until about the year 1882, when the ores from the New Caledonia mines began to flood the market. A period of over production followed, with its accompanying losses and uncertainties. The discovery of the Sudbury ores, in 1883, proved a still further disturbing feature, although, at the same time, it prompted and stimulated that scientific inquiry, which had been so long delayed, resulting in the discovery of several processes, some of which, although far from realizing expectations in regard to simplicity, economy and ease of manipulation, have produced metallic nickel, on a commercial basis, which contains as high as 99·70 to 99·82 per cent of fine nickel, the impurities being chiefly very small quantitles of carbon, iron and sulphur.

Supply of ore thought to be limited.

Entry on the market of New Caledonia ores.

Discovery of Sudbury deposits stimulated scientific enquiry.

Great purity of commercial nickel.

Another influence, which has contributed, in no small measure, to retard the progress of nickel metallurgy, and, no doubt, prevented the wide industrial employment of nickel, is the secrecy which has always been maintained by most companies, who have been or are engaged in the mining and smelting of nickel. This indifference, and, at times, positive unwillingness, to impart information, which would be of value or profit to the general public, has probably received no greater emphasis than in the case of nickel. Various excuses, more or less urgent or reasonable, are furnished by those in control, to account for their action in this respect, but gradually, this barrier of silence is being withdrawn, and, in the case of the Sudbury District, the managers of the two principal companies, have lately shown a commendable desire, to give all reasonable details in regard to the mining and smelting operations carrried on in Canada.

Unwillingness to give information on the part of nickel miners and smelters.

Lately all reasonable information cheerfully given by Sudbury companies.

This universal secrecy has, in the past, not only been maintained with regard to the exact location, extent and production of the individual mines themselves, but was especially extended to embrace the metallurgical treatment of the ores, even in the preliminary stages of roasting, matting and bessemerizing, while many of the small details, on which most of the success of the later refining methods depend, are still jealously repressed, or made known in such vague terms as to be

Secrecy was formerly maintained in every department of the industry.

practically valueless. All of our text books seem in symyathy with this lack of desire to impart information, and, in most of these, reference to the subject of nickel, or accurate and detailed knowledge in regard to this metal, is conspicuous by its absence. This secrecy was, no doubt, in the first place, prompted by the desire of deterring others from engaging either in the mining or refining of nickel, and if so, it has utterly failed in its purpose. It has permitted, and even greatly favored the spreading of the wildest and most exaggerated statements in regard to the enormous profits accruing to all engaged in this business.

Text books also fail to give adequate information.

Possible objects of secrecy.

The public, and especially those who are interested in mining, are being constantly apprised of the location of nickel deposits, which not only surpass all others in point of magnitude, but also in their peculiar adaptability for refining purposes. Further investigation, by competent individuals, (when such are available, or happily chosen), usually discloses some well known prospect or abandoned mine. On the other hand, men who are possessed of ample means, and are willing to devote a considerable portion to the promotion of some legitimate mining or smelting proposition, are often approached by so-called experts, with a supposed new and secret process, but which is already well known to a certain few, favoured individuals, who have already expended large sums, only to find that it is not a commercial possibility. Very few people have the necessary knowledge, or any means of verifying or refuting the statements of these interested individuals, and are thus often prompted to unusual and unwise expenditures, while, on the other hand, their ill success in these particulars prevents them from investing in some good, wholesome mining and-metallurgical enterprise, when occasion offers, which, if full details were available and offered, would not be the case. Fling wide the gates of knowledge; break down the barriers of silence; and it is confidently predicted that the resulting free and wide exchange of opinions and experience, will be of incalculable, benefit not only to the smelters and refiners, who are engaged in the nickel industry, but will prompt, encourage and direct the inquiring students and investigators of nickel, with profit to the whole of mankind.

Secrecy favours frauds on the public.

Prevents success of legitimate mining enterprises.

Exchange of opinion and experience of the widest benefit to all.

Numerous processes, for the refining of nickel, have been suggested and published, and, in many cases, elaborate experiments have been conducted, with varying degrees of success, to determine definitely their economic practicability. These could not be adequately or even satisfactorily discussed or explained, within the scope of the present report, even if all the necessary details were available for publication, but it may be well to refer, in general terms, to a few of those, which are

Numerous processes for refining nickel.

Scope of present report too limited for discussion.

either, at present, producing nickel on a commercial basis, or seem to give promise of doing so in the near future.

'Wet' and 'dry' processes embrace governing principles of all methods.

All of these methods are based on certain well known and long established principles, which have, in some instances, been worked out in more or less detail, and which are embraced under the general description of the so-called 'wet' and 'dry' processes. Certain minor changes and additions, chiefly in details, have made the latest refining of nickel much more readily and economically possible. Even with the present improvements, both are open to very serious and grave objections, as their adoption, in the first place, necessitates a very large and expensive plant, which is liable to frequent renewal and change, while the many complicated operations, which are still far from being fully understood, and the reactions appreciated, must entail a loss which is far from negligible. At the same time, however, the final product has, of late years, been all that could be desired from a commercial point of view. The 'wet' process, especially, which imitates, although on a large scale, the operations carried on in the chemical laboratory for the analysis of nickel, needs a very large and expensive plant, if any extensive output is contemplated. This must occupy a considerable area of ground, while a very long time must necessarily elapse, before the ore is sufficiently refined, to permit of its being placed upon the market. In the case of the Gap mine, it has been stated that a year sometimes passed from the time the ore was taken from the mine, before the product was in marketable shape.

Reaction not fully appreciated.

Wet process requires a large area for plant.

Combination of 'wet' and 'dry' processes in use at present.

The present methods of treatment make use of some of the more valuable features of both the 'wet' and the 'dry' processes, calling in the assistance of electrolysis in the final stages, and thus obtaining the metal in very pure form. In the treatment of the concentrated nickel-copper matte for the nickel-copper alloys, usually referred to under the general name of German silver, this bessemerized matte is first crushed to powder and roasted in a reverberatory furnace to remove all the sulphur, and the oxides are reduced directly to the alloy, either by smelting with charcoal or by reducing gases.

Manufacture of german silver.

Enumaration of principal processes.

In the treatment of the concentrated nickel-copper matte for nickel matte, nickel oxide and metallic nickel, the most important methods, for the separation of the nickel and copper, are the Orford or American process, the Mond process and some electrolytic processes.

Location of Orford Copper Co's refinery.

Nearly the whole of the matte, produced by the Canadian Copper Co., is refined by the Orford Copper Co., at their works, at Constable Hook, N. J., opposite Brighton, Staten Island, by what is known as the alkaline sulphide process. There is considerable dispute as to the

Discovery of alkaline sulphide process by Thompson.

Reported previous use of alkaline sulphide process.

Process would likely have been lost if not taken up by Orford Co.

origin of this process, some holding the discovery to be of recent date, while others contend that the principle, upon which it is based, has not only long been known, but has been in successful operation for many years. Mr. Robert M. Thompson, in an account of the discovery of this process, as far as the Orford Copper Co. is concerned, says that it was the result of an accident, following a long series of unsatisfactory experiments, to discover some process, which would successfully and economically treat certain mattes, which had been sold to the United States Government, by the Canadian Copper Co. In visiting the works one day, he noticed some pots of matte, which were cooling in front of the furnace, and which presented a somewhat unusual appearance. On calling attention to this fact, and failing to get satisfactory explanations from either the superintendent or foreman, he proceeded to investigate, the result being the discovery of the governing principle which effected the separation, and caused the yellow 'bottoms' and black 'tops.' After a long series of experiments, on a large scale, the process at present in operation, was gradually worked out. Mr. J. W. Bain, (1) in his 'Sketch of the Nickel Industry,' draws attention to the fact, that in certain descriptions accompanying applications for English patents, dating as far back as September 5th, 1839, undoubted reference is made to this principle. Moreover in a letter published in the Engineering and Mining Journal, in August, 1893, an ex-employee of the Vivian Company, at Swansea, states that the method had been employed for a number of years at that company's works. At any rate, the application of the alkaline sulphide process, as a definite scheme, for the separation of nickel and copper, was in a fair way of being lost to metallurgy, or, at least, to be employed in a very restricted manner, if the Orford people had not, so to speak, re-discovered the principle upon which it is based. Great credit is also due to this company, for the thorough manner in which they have worked out the details, and made it a distinct economic success.

Description of Orford or American process.

Formation and character of 'tops' and 'bottoms.'

In the Orford nickel process, the concentrated or bessemer matte is smelted in a small blast furnace, with salt cake or crude sodium sulphate, a chemical which can be obtained readily and cheaply. The sodium sulphate is reduced to sulphide, which forms, with the copper and iron sulphides, a very fluid matte, of lower specific gravity than the nickel sulphide. On cooling, 'tops' and 'bottoms' are easily separated; in the 'tops' being the bulk of the iron and copper as sulphides, together with sodium sulphide; while the 'bottoms' contain most of the nickel, with small quantities of iron and copper. On exposure to the weather, the soda in the tops is gradually converted into the caustic condition. These tops are now mixed with fresh matte and re-smelted, whereby the caustic soda is converted into sulphide of soda at the expense of the nickel in the bottom, producing again a fluid mixture of iron, copper and sodium sulphides while the nickel, in a semi-metallic state, sinks to the botton once more. By properly balancing these operations, a pure sulphide of nickel is at last obtained, which is simply calcined, with a little sodium nitrate to the nickel oxide of commerce. The oxide is either mixed with flour, molasses, etc., and pressed into cubes, or with charcoal, and reduced to metallic nickel in cube or powdered form. This product is not strictly a homogenous metal, but a loose sponge of metallic particles, which retain all the impurities contained in the oxide, with the addition of from 0.5 to 2 per cent of carbon. To produce the solid metal, the oxide is melted direct with charcoal and a small quantity of flux, and cast into ingots.

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(1) Ann. Rep. Bur. of Mines, Ont., 1900, p. 220.

Production of nickel oxide and metallic nickel.

Ulké's diagram of American or Orford process.

On the following page a diagramatic scheme, that accompanied a paper by Titus Ulké (1), is reproduced, which illustrates fully and briefly the various operations necessary in the Orford process:

Discovery and development of Mond process.

The Mond or carbon-monoxide process (2), is based on the fact, that if finely divided nickel, is exposed to a current of carbonic oxide, at a temperature below 150° C., a nickel carbonyl is formed, with the formula $Ni(Co)_4$, which is voiatile at a temperature above 43°C, and which is decomposed at a temperature of 180° C, into metallic nickel and carbonic oxide. Iron forms a similar carbonyl, but no other metal has been found to do so. In the process, there were many technical difficulties to overcome, and it was not until 1898, that it was brought to that stage of development, that demonstrated its practical importance.

Description of Mond process.

The bessemerized Victoria Mines matte is first dead roasted, and for this purpose, any suitable furnace may be employed. After roasting, the matte averages about 35 per cent of nickel, 43 per cent of copper and about 2 per cent of iron. It is than treated with dilute sulphuric acid, for the extraction of part of the copper, (about 66 per cent) and not above 2 per cent of the nickel. This copper is sold as crystallized sulphate of copper. The residue, after drying, from this operation, assays from 45 to 60 per cent of nickel, (averaging about 51 per cent) and 21 per cent of copper. The third operation, has for its object, the reduction of the nickel and, incidentally, the remaining copper, to the metallic state, without including the iron. For this

Formation of sulphate of copper.

Use of towers.

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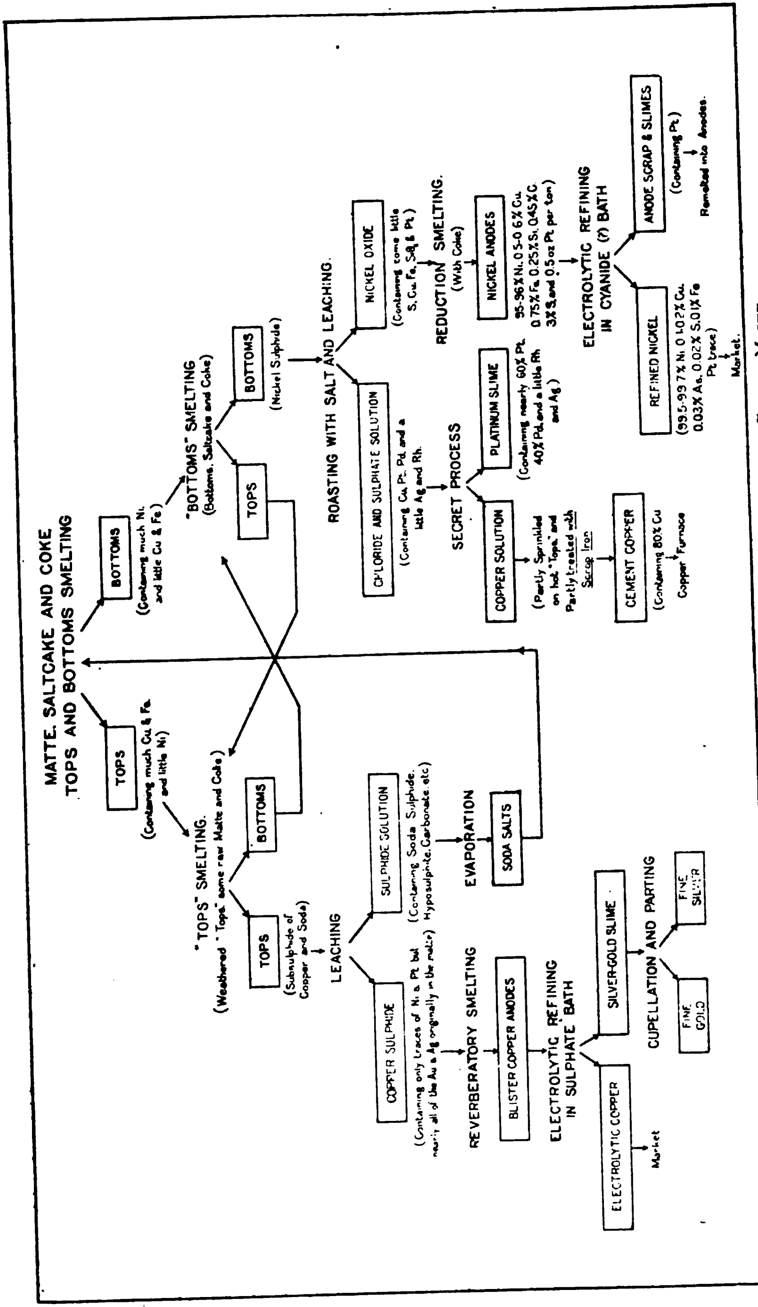
(1) Eng. and Min. Jour., Vol. LXIV., (July 3), 1897, pp. 8 9.

(2) Roberts-Austen 'Nickel Extraction by the Mond Process.' A paper read before the Institution of Civil Engineers, London, Eng., on the 8th November, 1898. Also Ann. Rep. Bur. of Mines, Ont., Vol. VIII., 1899, pp. 106-120.


MATTE, SALTCAKE AND COKE TOPS AND BOTTOMS SMELTING
TOPS
(Containing much Cu & Fe and little Ni)
BOTTOMS
(Containing much Ni and little Cu & Fe)
"TOPS" SMELTING.
(Weathered "Tops" some raw Matte and Coke)
"BOTTOMS" SMELTING
(Bottoms, Saltcake and Coke)
TOPS
(Subsulphide of Copper and Soda)
BOTTOMS
TOPS
BOTTOMS
(Nickel Sulphide)
LEACHING
COPPER SULPHIDE
(Containing only traces of Ni & Pt but nearly all of the Au & Ag originally in the matte)
SULPHIDE SOLUTION
(Containing Soda Sulphide, Hyposulphite, Carbonate, etc)
EVAPORATION
SODA SALTS
REVERBERATORY SMELTING
BLISTER COPPER ANODES
ELECTROLYTIC REFINING IN SULPHATE BATH
ELECTROLYTIC COPPER
Market
SILVER-GOLD SLIME
CUPELLATION AND PARTING
FINE GOLD
FINE SILVER
ROASTING WITH SALT AND LEACHING.
CHLORIDE AND SULPHATE SOLUTION
(Containing Cu, Pt, Pd and a little Ag and Rh.)
NICKEL OXIDE
(Containing some little S, Cu, Fe, Si & Pt)
SECRET PROCESS
PLATINUM SLIME
(Containing nearly 60% Pt, 40% Pd and a little Rh and Ag)
COPPER SOLUTION
(Partly Sprinkled on hot "Tops" and Partly treated with Scrap Iron)
CEMENT COPPER
(Containing 80% Cu)
Copper Furnace
REDUCTION SMELTING.
(With Coke)
NICKEL ANODES
95-96% Ni, 0.5-0.6% Cu, 0.75% Fe, 0.25% S, 0.45% C, 3% Si, and 0.5 oz Pt per ton)
ELECTROLYTIC REFINING IN CYANIDE (?) BATH
REFINED NICKEL
(99.5-99.7% Ni, 0.1-0.2% Cu, 0.03% As, 0.02% S, 0.1% Fe, Pt trace)
Market.
ANODE SCRAP & SLIMES
(Containing Pt)
Remelted into Anodes.

DIAGRAMMATIC SCHEME OF THE ORFORD METHOD OF TREATING NICKEL-COPPER MATTE.

purpose, it is treated in a tower 7.5m. high, and containing 14 hollow shelves, which are heated with water gas, to not more than 300°C, and preferably 250°, when much iron is present. The ore is moved, from shelf to shelf, by means of rakes, operated by a vertical axle. The lowest shelves are cooled. The reduced charge is transferred to another similar tower, where voltatilization takes place, in which part of the nickel is taken away by carbon monoxide, and forms the compound nickel carbonyl, but the temperature must not exceed 100°C. The remainder, from this volatilizer, is returned to the reducing tower, and the charge continues to circulate, between the two towers, for a period of between 7 and 15 days, until about 60 per cent of the nickel has been removed as nickel carbonyl. The nickel carbonyl passes to the decomposer, either a tower or a horizontal retort, which is heated to a temperature of 180°C, so as to decompose this compound, and release the nickel in a metallic state, preferably on granules of ordinary commercial metal. The carbon monoxide is also released, and is returned to the volatilizing tower, to obtain a fresh charge of nickel. The commercial product contains between 99.4 and 99.8 per cent of nickel. It has been stated, that Dr. Mond's process, although ingeniously and thoroughly worked out, has developed certain weaknesses, such as imperfect extraction of nickel, and the necessity of repeating certain of the operations several times before satisfactory results are achieved, and the larger proportion of the nickel obtained. The danger of explosion and poison, from the carbon monoxide gas, have all, seemingly, combined to delay the successful operation of this process, on a large scale for any protracted period.

Duration of operations.

Some objections urged to Mond's process.

THE HOEPFNER ELECTROLYTIC PROCESS.

Hoepfner electrolytic process.

In this process, a chloride solution is obtained, which has been freed from other metals, either chemically or electrolytically. The solution is neutralized, and then accidulated with some weak oxygen acid, such as citric or phosphoric acid, and the electrolysis effected with insoluble anodes. The anodes are immersed in a chloride solution of some more electro-positive metal than nickel. The cathodes are rotating or vibrating metal plates. The chlorine evolved is collected.

THE FRASCH ELECTROLYTIC PROCESS.

Short description of governing principles of Frasch process.

This process depends on the reaction in the electrolytic decomposition of common salt. At the anode, chlorine is evolved, at the cathode, sodium hydrate is formed by a secondary reaction. When applied to copper nickel matte, the anode consists of a layer of carbonaceous material. This is covered with a layer of matte, and the matte with a layer of sand, which serves as a diaphragm, between the anode and cathode sections. The chlorine evolved, dissolves the metals of the matte, forming chlorides. The solution is treated for the contained metals by electrolysis or chemically. From the solution of sodium hydrate at the cathode, caustic soda is obtained.

BROWNE'S ELECTROLYTIC PROCESS.

Main facts in regard to Browne's process.

In this process (1), the copper is first deposited from a solution of the mixed chlorides, using cathodes of pure copper and soluble anodes of copper nickel alloy. The original percentage of metal chloride in the electrolyte, is maintained, partly, by the solution of the anode and partly, by passing the electrolyte through a tower filled with bessemer matte or alloy to be treated, in contact with the chlorine gas evolved at the anode by the nickel precipitation.

When the electrolyte is rich in nickel, and nearly all the copper is deposited, the remaining copper is precipitated with hydrogen sulphide or a similar reagent, and the iron with ammonia. The nickel chloride solution is then electrolyzed, using cathodes of pure nickel and anodes of carbon, in water-sealed compartments, from which the chlorine is conducted to the regenerating tower.

ULKÉ'S ELECROLYTIC PROCESS.

Use of sulphate solution.

In this process, (2) a sulphate solution of the metals is used, instead of a chloride solution, as in the three processes described above.

General description of Ulké's continuous process for separating nickel and copper.

'With the Ulké process, it is most advantageous to use a material consisting of not over 20 per cent of nickel, and not less thaa 80 per cent of copper, which is cast into anode plates. The electrolyte consists of a solution of copper and nickel sulphate, and contains an excess of free sulphuric acid, and the cathodes are of pure sheet copper. The electrolyte is heated and kept in circulation and from time to time portions of it are withdrawn from the electrolytic vats to be re-standardized. The electrolyte withdrawn is replaced with an equal volume of copper sulphate solution, containing an excess of free acid to re-standardize the electrolyte. A portion of this copper sulphate is obtained as a by-product in the extraction of the nickel, as is outlined later in the description. The copper is precipitated (from withdrawn electrolyte) with hydrogen sulphide, and after filtering, the copper sulphide precipitate is treated with sulphuric acid and heat to recover the hydrogen sulphide and make the by-product copper sulphate. The nickel sulphate is made ammoniacal, and used hot as an electrolyte for

Production of copper sulphate.

(1.) Min. Industry, Vol. X, 1901, p. 497.
(2.) Min. Industry Vol. X., 1901, pp. 497-498.

the precipitation of nickel using anodes of lead and cathodes of sheet nickel. To avoid impoverishment of this electrolyte, portions of it are periodically withdrawn, the ammonia recovered for re-use and the nickel sulphate added to the electrolyte as needed to preserve the proper strength. The process is economical and produces nickel of high quality continuously and cheaply.'

Process economical and high grade of nickel produced.

Another process for the electrolytic winning of nickel, which is in successful operation, is the Balbach process, as carried on at the Balbach works, N. J. This process, however, is kept strictly secret.

NICKEL.

Discovery of nickel by Cronstedt.

Nickel is a comparatively new metal, as far as our western civilization is concerned, for it was discovered in 1751, by the Swedish metallurgist Cronstedt. It was, however, not until 1754, that Cronstedt definitely determined that it was a new element. Its name was given on account of its being a constituent of niccolite or 'kupfer-nickel' as it was then called. Cronstedt's discovery was made in examining the ore, obtained from the mines of He'singland. In 1776, Engstrom analyzed the material which had found its way to Europe, from China, under the name of 'Pachfong', finding it an alloy made up of variable quantities of copper, nickel and zinc, but usually present in the proportion of 40 per cent of copper, 15 per cent of nickel and 45 per cent of zinc. This alloy had been in use in China for thousands of years. Previous to this again, as noticed by Dr. Austen in his 'Historical Sketch of Nickel' the Bactrian King Euthydemos who reigned about 235 B.C., employed an alloy of nickel for coinage purposes, containing 77·58 per cent of copper, 20·04 per cent of nickel and 1·72 per cent of other impurities, such as iron, cobalt, tin, silver and sulphur. It is worthy of remark, that so long after this, the alloy at present in use for the manufacture of coins, is very similar in composition, containing about 75 per cent of copper and 25 per cent of nickel, which experience has taught us is the best proportion for such a purpose.

Analysis of China silver by Engstrom.

Nickel coins used 235 B.C.

Ancient coins made of same alloy at present used.

Physical properties of nickel.

Nickel, in its pure state, is silver-white in colour, hard, tough, fusible with difficulty, and is susceptible to magnetism, although not to the same extent as iron. It has the peculiar property of losing this magnetism when heated, and regaining it when cooled, this peculiarity being taken advantage of, in the manufacture of certain alloys for electrical purposes. Nickel has a specific gravity of 8·5 to 8·9.

Purity of nickel has steadily in-

The purity of the nickel, which has been on the market, has steadily increased since its first manufacture. This will be evident from the subjoined table of analyses of the commercial product. The three first analyses are quoted from the Mineral Industry, and were made in 1891. All the others were made in 1898 and 1899.

Authorities and references for analyses quoted.

Analyses of the nickel of commerce.

Table of Analyses of the Nickel of Commerce.

	I	II	III	IV	V	VI	VII	VIII	IX	X
Nickel	97.63	97.44	97.38	98.89	98.80	98.80	99.80	99.82	99.43	98.76
Cobalt	1.19	trace	1.70	0.14			none			
Iron	0.75	0.301	0.06	0.43	0 60	0.60	0.13	0.10	0.43	0.91
Copper	0.15		0.68	0.10	0.11		none			0·10
Sulphur	0.04	0.104	0.013		0·016	0.016	0.006	0.0068	0.0099	trace
Carbon				0.40	0.16	0.16	0.05	0.07	0.087	
Silicon				0.02	0.09	0.09	none			0.26
Manganese				0.02						
Tin					0.11					
Arsenic					0.11	0.11				none
Insoluble									0.026	
Carbon, Silicon, &c.	0.24	0.2155	0.167							

Analysis	I.	Rolled nickel anode (German); F. P. Dewey, analyst, 1891.
"	II.	Cast nickel, Gard, analyst 1891.
"	III.	Disk nickel; F. P. Dewey, analyst, 1891.
"	IV.	American nickel; by Forester, quoted by Ulké, Min. Ind. Vol VI, p. 595.
"	V.	Cubes; Ferro-nickel Co. Inst. Civil Eng., London, Eng., March 28, 1899.
"	VI.	Thompson nickel; Inst. Civ. Eng. London, Eng., Mar. 28, 1899.
"	VII.	Mond nickel; Inst. Civ. Eng. London, Eng., Mar. 28, 1899.
"	VIII-IX.	Mond nickel; Inst. Civ. Eng. London, Eng. Nov. 8, 1898.
"	X.	Wharton nickel; by J. W. Bain, Ann. Rep. Bur. of Mines, Ont. 1900, p. 223.

USES.

Nickel first used as German silver

The first and chief demand for this metal, was for making nickel or German silver, as a substitute for the more precious metal, in the manufacture of spoons, forks and other ware in general, for which silver had been previously used. Its whiteness, and the facility with which it received and held the silver, after the process of electro-plating was introduced, has caused it to be still more widely used. This use, however, has been replaced, in a large degree, by plating iron with nickel, which gives a very similar effect to German silver.

Nickel in electro-plating.

Nickel-plated iron.

Use of nickel for coins.

Nickel is also used very extensively for coinage purposes, both in Europe and America, these coins generally consisting of an alloy of from 75 to 88 per cent of copper, and 12 to 25 per cent of nickel. Recently, both Austria and Switzerland have authorized the use of pure nickel in coins.

Pure nickel now used in place of alloys.

Pure nickel is now used in making small articles, which formerly were only electroplated with nickel. An alloy, with 20 per cent of nickel and 80 per cent of copper, is used for casing bullets. This alloy has a higher degree of tenacity than the best brass, and a high co-efficient of elongation.

Intense colouring properties of nickel.

Owing to the intense colouring properties of nickel, (it is greater than that of any other metal except tin), these alloys have almost the same colour as the pure nickel.

Importation into Europe of Packfong or China silver.

In far more general use are the nickel-copper-zinc alloys. These were first introduced into Europe from China, in the eighteenth century, under the name of Packfong or China silver, and it was only later, that it was discovered that they consisted of nickel, copper and zinc. As European firms began to use these alloys, for manufacturing purposes, they gave them various names, such as german silver, argentan, etc.

Analyses of different varieties of 'New Silver.'

The following are analyses, from Ledebur's 'Technologie,' of some of these alloys:

	Copper.	Zinc.	Nickel.	Iron.
English new silver	63.34	17.01	19.13	0.52
Vienna " "	55.60	22.20	22.20	....
French " "	50.00	31.25	18.75	....
" " "	59.10	30.20	9.70	1.00
" " "	69.90	5.60	19.80	4.70

'New Silver' used for various purposes.

The chief uses of these alloys are for forks, spoons, etc., and various household goods to be silver-plated, and for many scientific instruments, where brass was formerly used.

A little magnesium, added to nickel when in a molten state increases its malleability, and this property has been utilized in the manufacture of nickel into sheets, and also in making sheets composed of an iron plate, with a nickel plate welded upon each side of the iron; the mass then becoming capable of being rolled to any desired thickness. This rolled nickel plate is an advance over ordinary tin plate, for culinary and other utensils.

Addition of magnesium to nickel increases malleability.

Rolled nickel plate.

Nickel-plated zinc or 'nickeloid,' as it is called, is being used to a considerable extent in the manufacture of reflectors, refrigerator linings, baths, etc.

Nickeloid.

The most important and extended use of nickel, however, is in the manufacture of nickel steel, and, at present, we must look to its more general employment in this direction, as replacing carbon and manganese steel, for the development of the nickel industry. The peculiar and desirable behaviour of nickel, in alloy with other metals, and especially with iron and steel, has often been remarked, the material partaking more of a chemical combination than an ordinarily intimate mixture. All these alloys are remarkably homogeneous, and susceptible of a high polish, though rather difficult of manipulation. In obtaining a correct idea of the usefulness or value of alloys of nickel with iron and steel, it should be borne in mind that these mixtures contain manganese, carbon, silicon, sulphur and phosphorus, whose influence must be carefully watched, requiring a long series of experiments. A comparison of steel alloyed with 4.7 per cent of nickel, raised the elastic limit from 16 up to 28 tons, and the breaking strain from 30 up to 40 tons, without impairing the elongation or contraction of area to any appreciable extent. A further gradual increase of hardness was noticed until 20 per cent is reached, when a change takes place, and successive additions of nickel tend to make the steel softer, and more ductile. The alloys polish well, and the colour of the steel is lightened, as the proportion of nickel is increased. They do not corrode as readily as other steel. The one per cent nickel steel welds fairly well, but this property lessens with each addition of nickel. It may, therefore, be said that considerable advantage can be expected from these alloys, especially where the amount of nickel present is less than 5 per cent. Nickel steel is now being used for a variety of purposes, among which may be mentioned rails for railways. These have been tried for a number of years, at Cumberland Gap, in the United States, and have given very great satisfaction. The first cost is considerably higher, but they can be made much lighter, and will outlast three ordinary steel rails. Its most important use, however, is for armour plates and

Use of nickel in alloy with steel.

Peculiar nature of alloys.

Good qualities of alloys.

Impurities in nickel steel.

Strength of nickel steel.

Physical characters of nickel steel alloys.

Uses of nickel steel.

Nickel steel rails.

heavy ordnance. For machine parts, subjected to alternate stress and shock, and where increase of strength and decrease of weight are desired, it is unrivalled. On account of this marked quality, it has been used for engine and propeller shafts, and has proved so much superior to all other steels for this purpose, that it has no rival of importance. Owing to its resistance to 'fatigue' from persistent vibration and concussion, it is particularly valuable for steam hammer piston rods, rock drill piston rods, railway axles, or tank pins; also for light forged engine frames, bolts for extreme hydraulic pressure, bicycles, etc. It has also been recommended for the manufacture of dies and shoes, in stamp mills, and of wire rope. Nickel steel wire rope would be less corrosive, and have more tensile strength, than the ordinary steel wire ropes, in use at present.

Use of nickel steel in machine parts

Use in propeller shafts, rock drills, &c.

Nickel steel wire rope.

Co-efficient of expansion of nickel steel.

The co-efficient of expansion of nickel steel with 36 per cent of nickel, is only 0.00000087, that of ordinary materials varying from 10 to 20 times this figure. This low co-efficient of expansion will likely be of great value for many purposes. Alloys with 42 to 46 per cent of nickel, have the same co-efficients of expansion as various sorts of glass, which will make them valuable in replacing the more expensive platinum, in cases where metal and glass have to be welded together.

Other alloys of nickel are mentioned in "The Mineral Industry" Vol. X. They are nickel-aluminium, with a tensile strength of 40,000 lbs. per sq. in. and an elastic limit of 35,000 lbs. per sq. in.

Composition of chrome-nickel.

Chrome nickel, containing usually 73 per cent of chromium, 23 per cent of nickel, 2.5 per cent of iron, 1 per cent of carbon and 0.5 per cent of silicon, is used in making steel for projectiles and armour plates, which is said to be better than Harveyized steel armour plates. Tungsten-nickel has a composition similar to chrome-nickel, tungsten taking the place of chrome.

Tungsten-nickel.

Composition of molybdenum-nickel.

Molybdenum-nickel with 45 to 75 per cent of molybdenum, 20 to 50 per cent of nickel, 2 to 2.5 per cent of iron, 1 to 1.5 per cent of carbon and 0.25 to 0.50 per cent of sulphur is largely used in the manufacture of forgings, guns, wire, boiler-plate and shells.

The era of nickel steel has just been entered upon.

The era of nickel steel has only been entered upon, for it was not until 1888, that this desirable alloy was made, on any scale of commercial importance. Canada has the largest supply of the most desirable nickel ores in the world, and the quality of the metallic nickel, as shown by the analyses quoted, is of a very high degree of purity. It is beyond the scope of the present report, to enter upon a discussion of the manifold merits of nickel steel, and the numerous benefits to be derived from its use. In 1899, Messrs. R. A. Hadfield (¹) and David H. Browne (²), published two very complete contributions on this subject, and the reader may have reference to these for more detailed information. Lately, Dr. Waddell has been employed, under the auspices of the International Nickel Company, in making an elaborate series of tests and experiments, with nickel steel, with special reference to its more extended use in bridge building. The general public, and more particularly, that numerous soction of it in Canada, who are interested in the extension of the nickel industry, will look forward with pleasure to the appearance of Dr. Waddell's conclusions, which, it is hoped, will not be witheld, on the plea that the information is of a confidential nature.

Papers on nickel-steel bv Hadfield and Browne.

Experiments for International Nickel Company by Dr. Waddell.

PRODUCTION OF NICKEL AND COPPER FROM THE SUDBURY DISTRICT.

It is difficult to obtain the exact production of the nickel and copper ores of the Sudbury District, during the first three years of mining from 1886 to 1888, inclusive. Thus, R. R. Maffett, Superintendent of the Orford Copper company, at New Brighton, L. I., N. Y., under date of April 18, 1904, answering an inquiry addressed to President A. P. Turner, of the Canadian Copper Company, at Copper Cliff, Ont., states, that during 1886, 1,040 tons of ore, carrying 7.2 per cent of copper and 3 per cent of nickel, were mined at Copper Cliff, and during 1887, 8,864 tons carrying 8.56 per cent of copper and 3.31 per cent of nickel, were also raised from the the same mine. According to details, furnished the Geological Survey Department, by the Customs Department, 3,307 tons of copper ore were shipped from Sudbury, in 1886, with a declared customs value of $16,404, and in 1887, 567 tons of similar ore were also shipped, with a declared customs value of $3,416. A careful and conservative estimate, to arrive at the total production, would place the amount mined during these three years at 30,000 tons, averaging about 5 per cent of copper and 3 per cent of nickel, this ore thus containing, approximately, 900 tons of nickel; and 1,500 tons of copper. Valuing the nickel, at the average price for the three years, at 62.12 cents per lb., the total ultimate value of the nickel in the ore, would amount to $1,118,160, while the copper, at the average price of 12 cents per pound, would amount to $360,000. According to the yearly returns, furnished the Geological Survey Department and the Ontario Bureau of Mines, the total ore mined in the district, including the estimate as above given for the first three years, has amounted to 2,093,427 tons. The total amout of nickel in matte, sold from 1889 to 1903, both years inclusive, amounted to 39,827 tons, with a final value in New

Figures of early production of nickel in Sudbury District difficult to obtain.

Returns for 1886-87 by Canadian Copper Company.

Shipments of ore according to Customs Department.

Estimate of production in three first years.

Value of metals produced during first three years.

Matte sold from 1889-1903 inclusive.

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(1) Proc. Inst. Civil Eng., London, Vol. CXXX., pp. 1-167.

(2) Trans. Am. Inst. Min. Eng., Vol. XXIX., (Sept.), 1899, pp. 569-648.

Total amount and value of nickel and copper produced.

York, at the lowest average prevailing price in the year in which it was placed upon the market, amounted to $35,603,272, while the copper present in the matte, in the same period, amounting to 37,429, tons valued at the average price of copper in the year sold, realized $9,799,730. If we include the three first years, at the figures already given, we obtain a total amount of nickel sold of 40,727 tons, with a value of $36, 721, 432; while the copper amounted to 38,929 tons, with a value of $10,159,739.

Estimate of cobalt contents of matte.

Average contents of precious metals per ton of pure nickel.

Values of precious metals.

This nickel and copper ore also contains cobalt, and an average of a large number of assays, would indicate that the proportion of nickel to cobalt as 50 to 1, is a conservative estimate. If all of this could have been saved, 815 tons of cobalt would have been thus produced, and this, at a price of $3.00 per lb., would have amounted to $4,890,000. In addition, these ores contain appreciable quantities of the precious metals, gold, silver and metals of the platinum group. The platinum metals average about 1.25 oz., the gold 0.375 of an ounce, while the silver has been calculated on the assumption that 7.5 oz. are present to the ton of nickel, which is certainly below the average. On this assumption, the value of the precious metals, at the average of the ruling New York price in the years produced, would be as follows: Gold $305,460; Silver, $195,286; Platinum, $805,429; Total, $1,306.175. The total ultimate value in New York, of the various metals contained in these ores, would, therefore, be as follows:

Values of total production.

Nickel	$36,721.432
Cobalt	4,890.000
Copper	9,799.739
Gold	305.460
Silver	195.286
Platinum	805,429
Total	$52,717.346

Total production of ore from Canadian Copper Co's mines.

Of the total production of ore, about four-fifths must be credited to the Canadian Copper Company. This company does not wish, at present, to give the production of each individual mine, but through the courtesy of President A. P. Turner of the Canadian Copper Company, I am authorized to state that the three largest of their mines, have produced the following amounts of ore, up to the first of June, 1904.

Stobie Mine	419,000 tons
Copper Cliff Mine	366,000 "
Creighton Mine	310,000 "

Some of the other mines have also produced large quantities of ore, as the Evans mine, No. 2 and No. 3 (Frood mine) mines all three of which have produced between 100,000 and 200,000 tons of ore. The Creighton mine is, without doubt, the largest mine in the district, and is regarded as capable of producing many millions of tons of high grade ore. The ore at present being mined averages about 5 per cent of nickel and 2 per cent of copper. During the month of May last (1904) 19,000 tons of ore were mined, and, in June, it was expected that 22,000 tons would be secured. It is proposed, in the near future to erect another rock house, further west, on this same deposit, when the output will be nearly doubled. The old Blezard mine, belonging to the Dominion Mineral Company, probably produced about 100,000 tons of ore, while 25,000 tons seems a reasonable estimate for that produced by the Worthington mine. The Victoria mine, belonging to the Mond Nickel Company, has produced about 80,000 tons of ore, while the same company, up to the 1st of June, 1904, had obtained about 13,000 tons from the North Star mine. At the Murray mine, 62,193 tons were produced, while the Lake Superior Power Company obtained 33,835 tons from the Elsie Mine, and 18,000 tons from the Gertrude mine, up to the end of 1903.

Creighton mine reserves of ore.

Large production of high grade ore from Creighton mine.

Production from Dominion Mineral Co's mines.

Production of ore from Victoria mine.

North Star mine.

Murray, Gertrude and Elsie mines.

The following tables are reproduced from the annual reports of the Division of Mineral Statistics and Mines, of the Geological Survey Department, and of the Bureau of Mines, of Ontario. Both have been prepared by Mr. J. McLeish, who has charge, under Mr. E. D. Ingall, of this branch of the work. They will show, in a diagrammatic manner, the details of the mining operations, carried on in the district from 1889 to 1903, both years inclusive.

Tables of production prepared by Mr. J. McLeish.

Production of Nickel and Copper, Sudbury District, Ontario, according to the Mines Section, Geological Survey.

Calendar Year.	Ore mined.	Ore treated.	Ordinary matte sold and shipped.	High grade matte sold and shipped.	Spot value of matte.	Nickel contents of matte sold.	Final value of nickel.	Copper contents of matte sold.	Final value of copper.
	Tons.	Tons.	Tons.	Tons.	$	Tons.	$	Tons.	
1886	3,307	30,000?							
1887	567					900?	1,118,160?	1,500?	360,000?
1888									
1889	44,990	40,146	3,274			432	518,602	733	201,678
1890						718	933,232	651	205,233
1891	83,300	72,558	10,336			2,018	2,421,208	2,064	531,234
1892	74,381	57,022				1,207	1,399,956	1,102	254,538
1893			9,425			1,991	2,071,151	1,821	391,461
1894	103,223	96,038	11,681		766,422	2,454	1,870,958	2,604	497,854
1895	74,135	68,618	10,188		890,834	1,944	1,360,984	2,288	492,414
1896	94,966	71,027	10,759		416,594	1,699	1,188,990	1,584	344,598
1897	93,154	96,370	13,968			1,999	1,399,176	2,750	621,023
1898	123,820	121,924				2,759	1,820,839	4,187	1,007,539
1899	159,957	172,761			702,341	2,872	2,067,840	2,834	998,135
1900	196,420		23,336		1,076,306	3,540	3,327,707	3,364	1,089,383
1901	315,692	255,958			1,661,839	4,594	4,594,523	4,318	1,392,018
1902	269,538	211,847	23,211	2,100	1,327,448	5,347	5,025,903	3,553	826,175
1903	136,033	207,030		13,832	2,686,469	6,253	5,002,204	3,576	946,456

Production of Nickel and Copper, Sudbury District, Ontario. Compiled from the Annual Reports of the Ontario Bureau of Mines.

Year.	Ore raised.	Ore smelted.	Ordinary matte produced.	High grade matte produced.	Spot value of matte.	Per cent of Ni and Cu contents in ore smelted.		Ni contents of matte.	Cu contents of matte.	Cobalt.	Spot value of nickel in matte.	Spot value of copper in matte.	Spot value of cobalt in matte.	Wages paid.	Men employed.
	Tons.	Tons.	Tons.	Tons.	$	Ni.	Cu.	Tons.	Tons.	To's	$	$	$	$	
*1890	130,278	59,329	....	....	....	.....	...	....	......	....	....	......	....	....	....
*1891	85,790	71,480	....	....	....	.....	.....	....	......	....	....	......	....	....	....
*1892	72,349	61,924	6,278	1,880	826,750	3.362	3.126	2,080	1,936	8½	590,902	232,135	3,713	339,821	690
*1893	64,043	63,944	7,176	452	539,302	2.585	2.237	1,653	1,431	19	445,702	115,200	9,400	252,516	495
*1894	112,037	87,916	10,410	1,470	809,974	2.924	3.125	2,570⅓	2,748	3¼	612,724	195,750	1,500	311,719	655
*1895	75,439	86,546	12,525	103	565,774	2.675	2.733	2,315¾	2,365¾	...	404,861	160,913	....	209,960	444
1896	109,097	73,505	9,733	......	487,660	2.651	2.534	1,948½	1,868	....	357,000	130,660	....	247,151	485
†1897	93,155	96,094	13,706	328	559,718	2.080	2.861	1,999	2,750	....	359,651	200,067	....	253,226	535
†1898	123,920	121,924	21,101	....	782,300	2.283	3.433	2,783¾	4,186¾	...	514,220	268,080	....	315,501	637
†1899	203,118	171,230	19,109	106	702,340	1.677	1.655	2,872	2,834	....	526,104	176,236	....	443,879	839
†1900	216,695	211,960	23,336	112	1,076,307	1.670	1.587	3,540	3,364	....	756,626	319,681	....	728,946	1,444
†1901	326,945	270,380	29,588	15,546	2,449,050	1.642	1.552	4,441	4,197	...	1,859,970	589,080	....	1,045,889	2,284
1902	269,538	233,388	24,691	13,332	2,827,724	2.547	1.742	5,945	4,066	...	2,210,961	616,763	....	835,050	1,445
†1903	152,940	220,937	30,416	14,419	3,082,714	3·167	1,812	6,998	4,005	....	2,499,068	583,646	....	746,147	1,277
†															

* Year ending 31st October.
† Year ending 31st December.

THE WORLD'S PRODUCTION OF NICKEL.

Early production of nickel.

From 1840 to 1860, the annual production of nickel scarcely averaged 100 metric tons per annum, and in no single year was a production of 200 metric tons exceeded. From 1860 to 1880, a very gradual, though distinct, increase was noticeable, up to 600 metric tons, although, about the year 1874, a little over 700 metric tons were produced. In 1880, the product of the New Caladonia mines became a distinct factor on the market, at first with a production of about 200 metric tons per annum, but gradually increasing until the year 1884, when the production was about 1,000 tons. In the year 1889, the product of the Sudbury mines was placed upon the market, but only 432 tons were sold. In the year 1891, however, 2,018 tons (1,830 metric tons) of nickel were sold which had been produced from the Sudbury ores, while, at the same time, the product of the New Caledonia mines, which had reached the figure of 2,494 metric tons, dropped to 1,696 metric tons in 1892. In 1893, the world's total production of nickel amounted to 4,412 metric tons, the amount of the Canadian product placed on the market, aggregating 1,807 metric tons; while Norway, in the same year, produced about 90 metric tons, and the United States 22·4 metric tons.

Early production of nickel from New Caledonia mines.

Large increase in production of nickel.

These figures showed a still further and rather rapid increase up to the year 1901, when a total of 9,381 metric tons were produced, the Canadian nickel amounting to 4,168 metric tons, and the New Caledonia to 5,210 metric tons, while the United States produced only 3 tons of nickel from domestic ores.

Canada leads in production of nickel.

In 1902, the total of the world's production, amounted to 8,473 metric tons, but of this Canada's share was 4,850 tons, while the New Caledonia output showed a decrease to 3,620 tons.

In 1903, the amount of Canadian nickel produced amounted to 6,348 metric tons, while New Caledonia produced only 4,750 metric tons.

Future of Canadian nickel.

The world's total production of nickel for 1903 as stated by the Metallgesellschaft amounted to 9,850 metric tons. It is evident, however, that this is understated and that the actual production is considerably in excess of this amount, for the official returns for Canada and the United States, as reported to the Geological Survey and the Bureau of Mines of Ontario, give the production as 6,400 metric ton, sinstead of 5,100 metric tons, as stated by this authority. Assuming the official figures as more nearly accurate and adding the production from New Caledonia as quoted by the Metallgesellschaft (4,750 metric tons), a grand total of 11,150 metric tons is obtained, as the aggregate of the world's production for 1903.

World's production of nickel.

These figures are full of hope for Canada, and with the gradually increasing knowledge of the true value and uses of nickel, by reason of its many desirable physical qualities, which is gradually becoming more general, the production of nickel should be doubled in the next five years. It is hoped and confidently expected, that Canada's share in this large output, will be fully three-fourths of the whole.

The following table will show, at a glance, and in much greater detail, the world's annual production of nickel, from 1889 to 1902. The figures for the foreign production for 1903 are not yet available.

These statistics are obtained mainly from the Metallgesellschaft and Metallurgische Gesellschaft (Frankfort on-the-Main), Aug., 1903, p. 23.

Authorities and references for table of world's production of nickel.

The production of nickel from domestic ores in the United States is quoted from Mineral Resources of the United States while that of Canada is from the Division of Mineral Statistics and Mines, Geological Survey of Canada, with the exception of 1903, which is from the Bureau of Mines. The figures of Canadian production, include nickel actually, sold while those of the Bureau of Mines, which are stated in a separate table, are of nickel produced, part of which remained in stock.

Details of nickel production from Saxony not available.

The figures for Germany, represent the production of Prussia. Saxony also produces nickel, but accurate details are not readily available.

THE PRICE OF NICKEL.

Large prices prevailing at first.

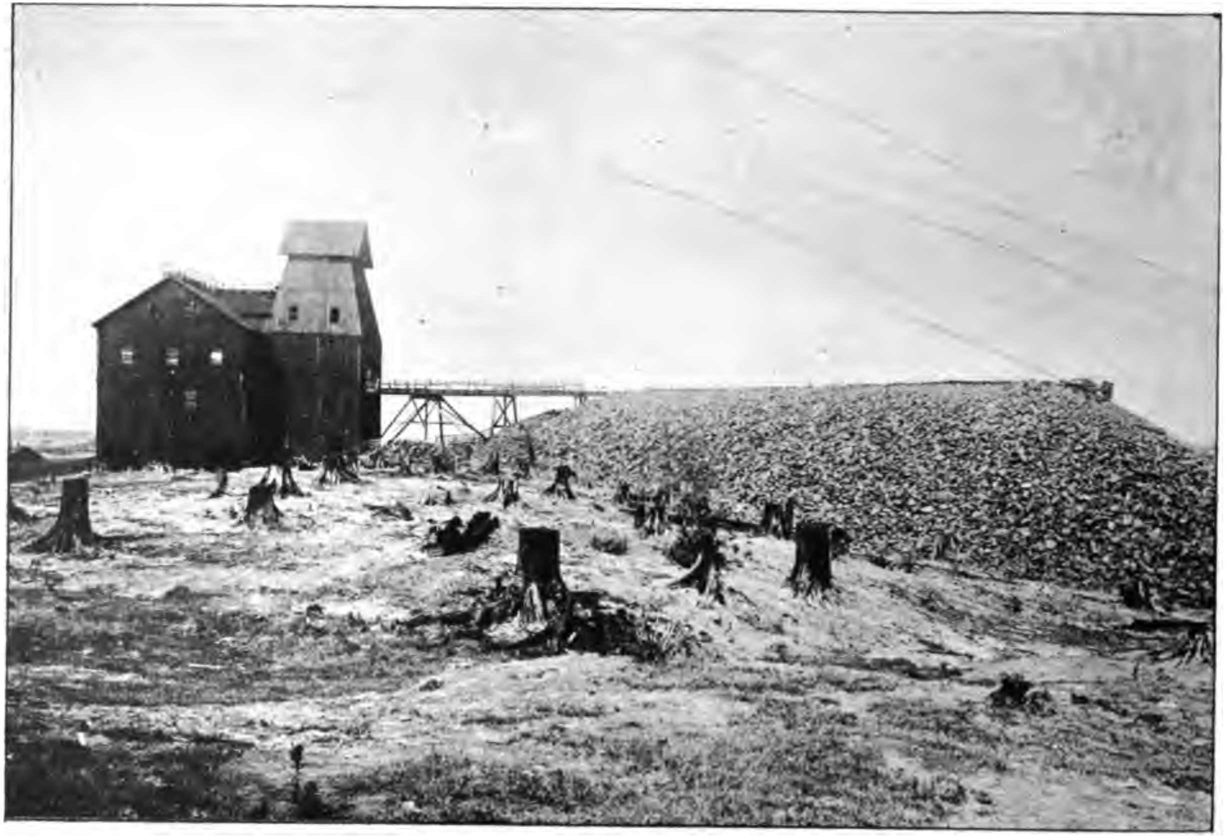
Gradual decrease in price.

Present price of nickel.

In 1876, the price of nickel per lb., amounted to $2.60. In 1877 it dropped to $1.60 per lb., and in 1878, it showed a still further decline to $1.10 per lb. In 1879, it recovered slightly to $1.12 per lb. but in 1880 it again decreased to $1.10, which latter figure was maintained until 1883, when the price steadily declined to about 60 cents. At present, the price quoted by leading producers, varies from 40 to 47 cents per lb., for large quantities down to ton lots, according to size and terms of order. The price for smaller lots, according to quantity, runs as high as 60 cents per lb., in New York.

World's Production of Nickel (in metric tons).

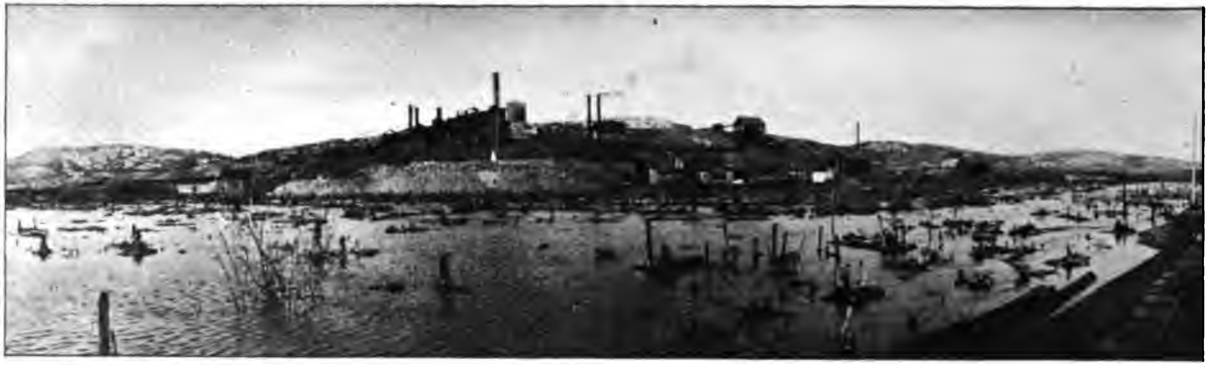
<table>
<tr><th rowspan="2">Year.</th><th rowspan="2">Sweden and Norway.</th><th colspan="3">Nickel contents of ores exported from New Caledonia.</th><th rowspan="2">Total. (New Caledonia.)</th><th rowspan="2">Canada.</th><th rowspan="2">United States.</th><th rowspan="2">Grand total.</th><th rowspan="2">Average price per lb. in New York.</th></tr>
<tr><th>Germany.</th><th>France,</th><th>Great Britain.</th></tr>
<tr><td>1889</td><td>80</td><td>282</td><td colspan="2">1,050</td><td>1,332</td><td>377</td><td>114·606</td><td>1,904</td><td>60 c.</td></tr>
<tr><td>1890</td><td>100</td><td>434</td><td colspan="2">1,200</td><td>1,634</td><td>651</td><td>101·372</td><td>2,486</td><td>65 c.</td></tr>
<tr><td>1891</td><td>125</td><td>594</td><td colspan="2">1,900</td><td>2,494</td><td>1,830</td><td>53·750</td><td>4,503</td><td>60 c.</td></tr>
<tr><td>1892</td><td>97</td><td>746</td><td colspan="2">950</td><td>1,696</td><td>1,095</td><td>41·845</td><td>2,930</td><td>58 c.</td></tr>
<tr><td>1893</td><td>90</td><td>893</td><td colspan="2">1,600</td><td>2,493</td><td>1,807</td><td>22·407</td><td>4,412</td><td>52 c.</td></tr>
<tr><td>1894</td><td>90</td><td>522</td><td colspan="2">1,900</td><td>2,422</td><td>2,226</td><td>4·362</td><td>4,742</td><td>38⅛ c.</td></tr>
<tr><td>1895</td><td>40</td><td>698</td><td colspan="2">1,850</td><td>2,548</td><td>1,764</td><td>4·673</td><td>4,357</td><td>35 c.</td></tr>
<tr><td>1896</td><td>20</td><td>822</td><td>1,545</td><td>340</td><td>2,707</td><td>1,541</td><td>7·788</td><td>4.276</td><td>35 c.</td></tr>
<tr><td>1897</td><td>........</td><td>898</td><td>1,245</td><td>715</td><td>2,858</td><td>1,813</td><td>10·753</td><td>4,682</td><td>35 c.</td></tr>
<tr><td>1898</td><td>........</td><td>1,108</td><td>1,540</td><td>1,000</td><td>3,648</td><td>2,503</td><td>5·055</td><td>6,156</td><td>33 c.</td></tr>
<tr><td>1899</td><td>........</td><td>1,115</td><td>1,740</td><td>1,350</td><td>4,205</td><td>2,605</td><td>10·224</td><td>6,820</td><td>36 c.</td></tr>
<tr><td>1900</td><td>........</td><td>1,376</td><td>1,700</td><td>1,450</td><td>4,526</td><td>3,211</td><td>4·407</td><td>7,741</td><td>47 c.</td></tr>
<tr><td>1901</td><td>........</td><td>1,660</td><td>1,800</td><td>1,750</td><td>5,210</td><td>4,168</td><td>3·039</td><td>9,381</td><td>50 c.</td></tr>
<tr><td>1902</td><td>........</td><td>1,604</td><td>1,110</td><td>1,310</td><td>4,024</td><td>4,850</td><td>2·607</td><td>8,877</td><td>47 c.</td></tr>
<tr><td>1903</td><td>........</td><td>1,600</td><td>1,500</td><td>1,650</td><td>4,750</td><td>6,348</td><td>51 801</td><td>11,150</td><td>40 c.</td></tr>
</table>



Evans mine, Canadian Copper Co., Copper Cliff, Ont.

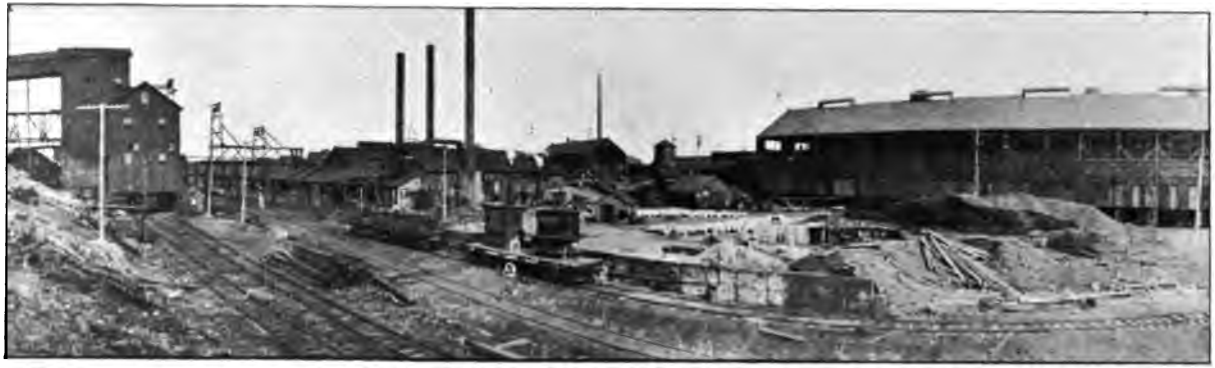
THE TOWN OF COPPER CLIFF, ONT.

WEST SMELTER OF CANADIAN COPPER CO., AT COPPER CLIFF, ONT.

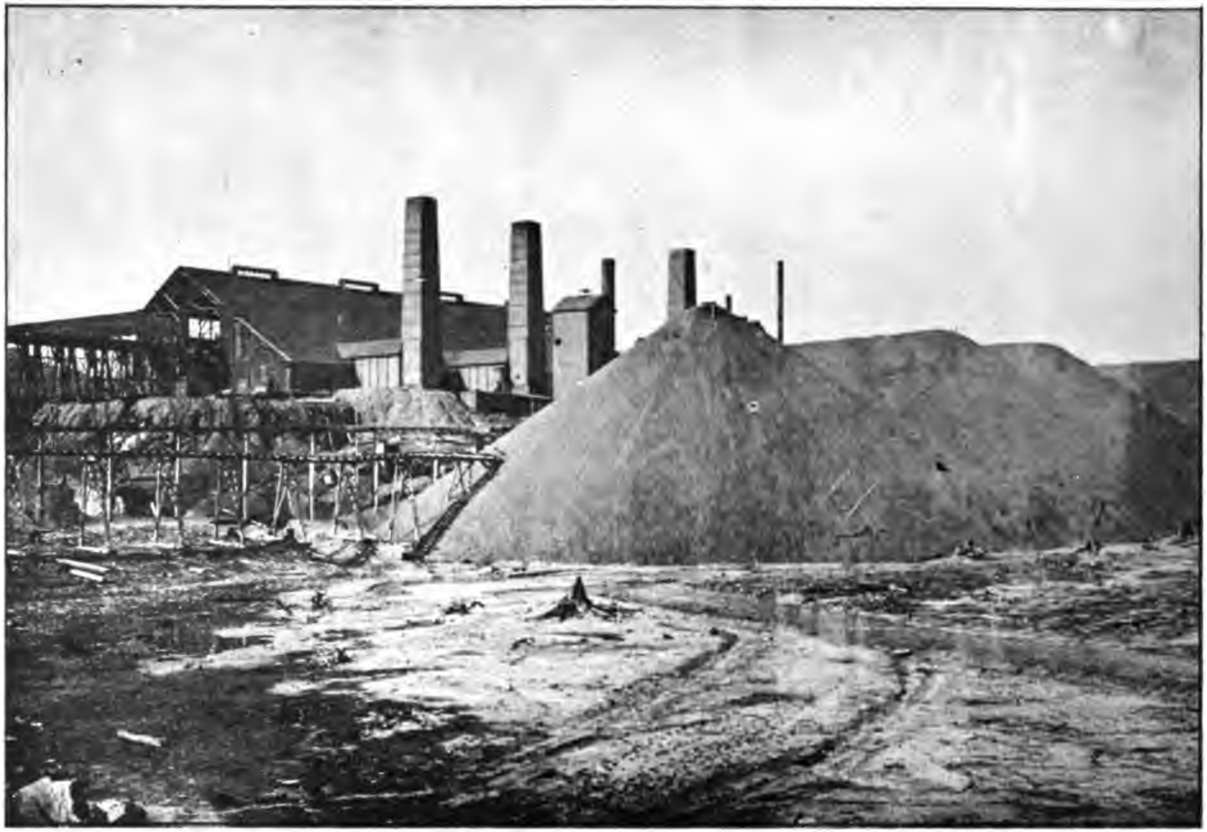


THE ONTARIO SMELTING WORKS, ORFORD COPPER CO., AT COPPER CLIFF, ONT.

These buildings were destroyed by fire in the spring of 1904.

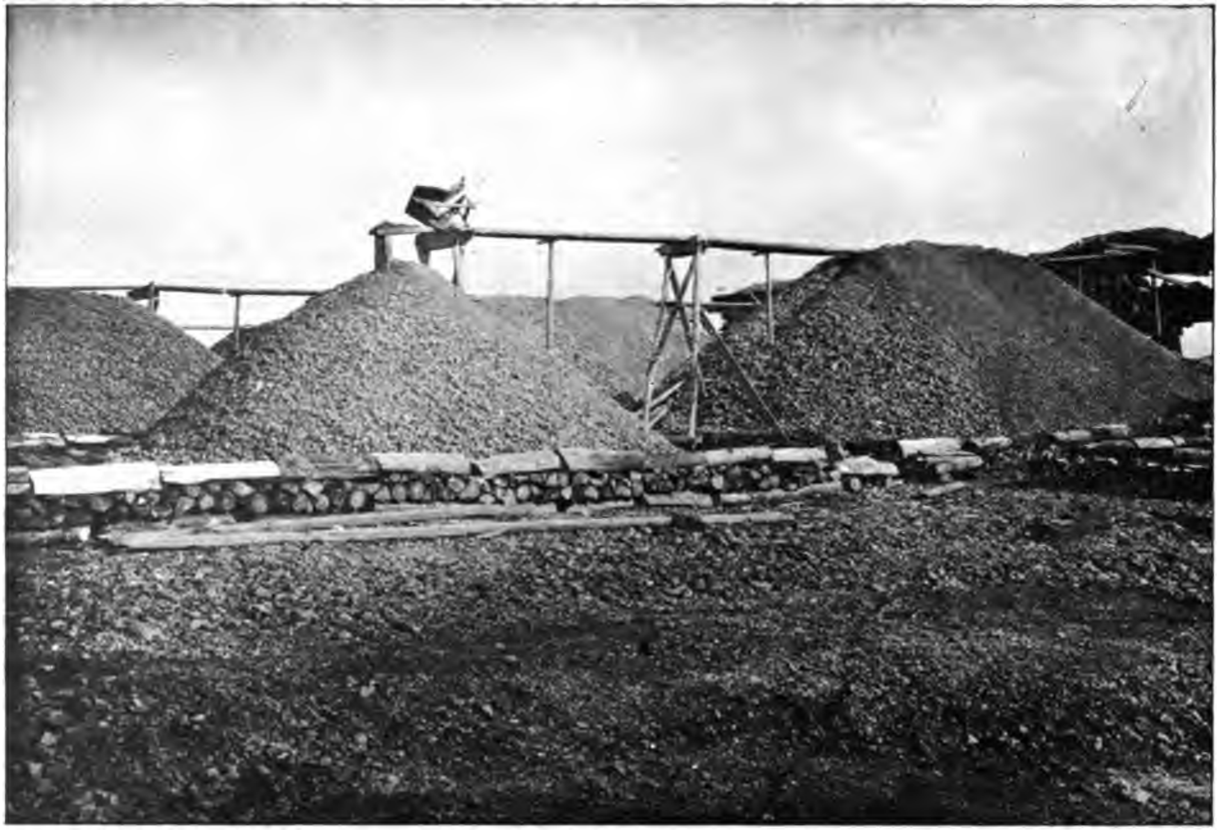


NO. 2 MINE, WEST SMELTER AND MATTE SHIPPING YARD, CANADIAN COPPER CO., COPPER CLIFF, ONT.

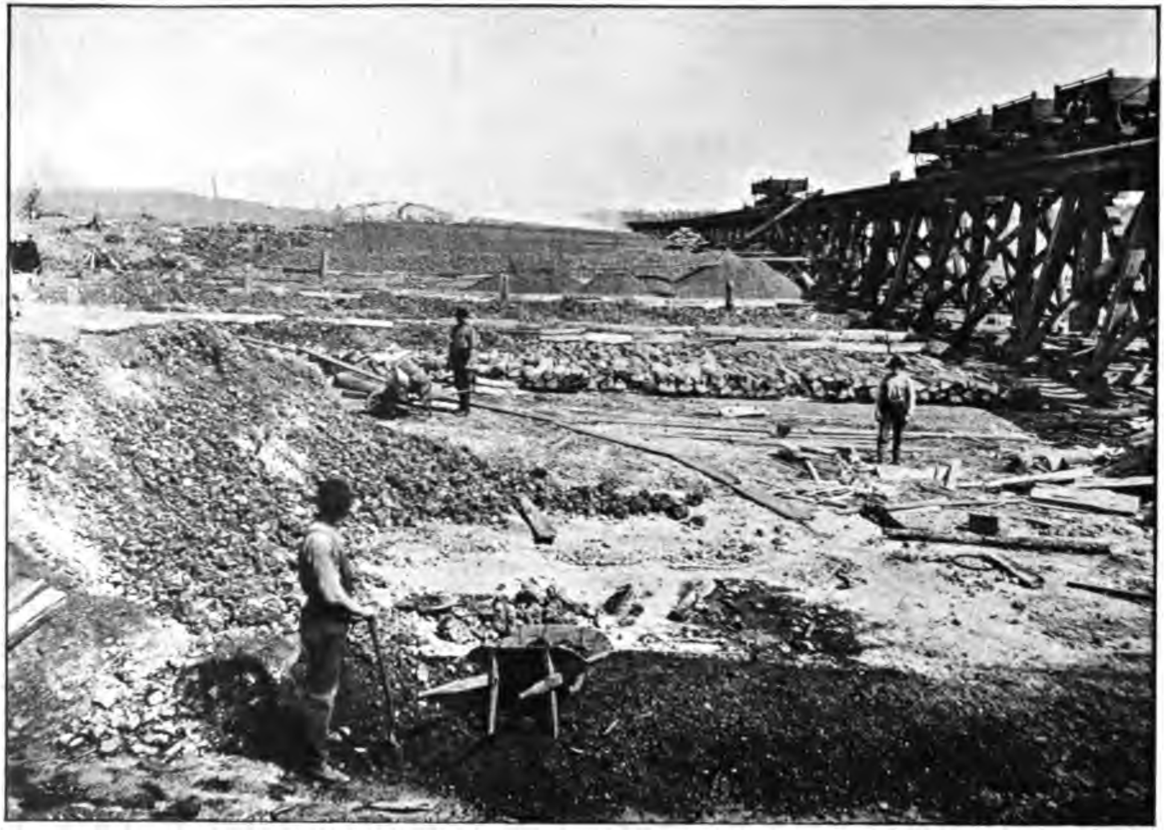


THE WEST SMELTER OF THE CANADIAN COPPER CO., AT COPPER CLIFF, ONT.

This view looking N.E. was obtained from the high trestle leading from the lower roast yard. The high dumps of granulated slag are prominent in the foreground.



Roast yard at Copper Cliff, Ont.
Showing temporary trestle and general method of building roast heaps.

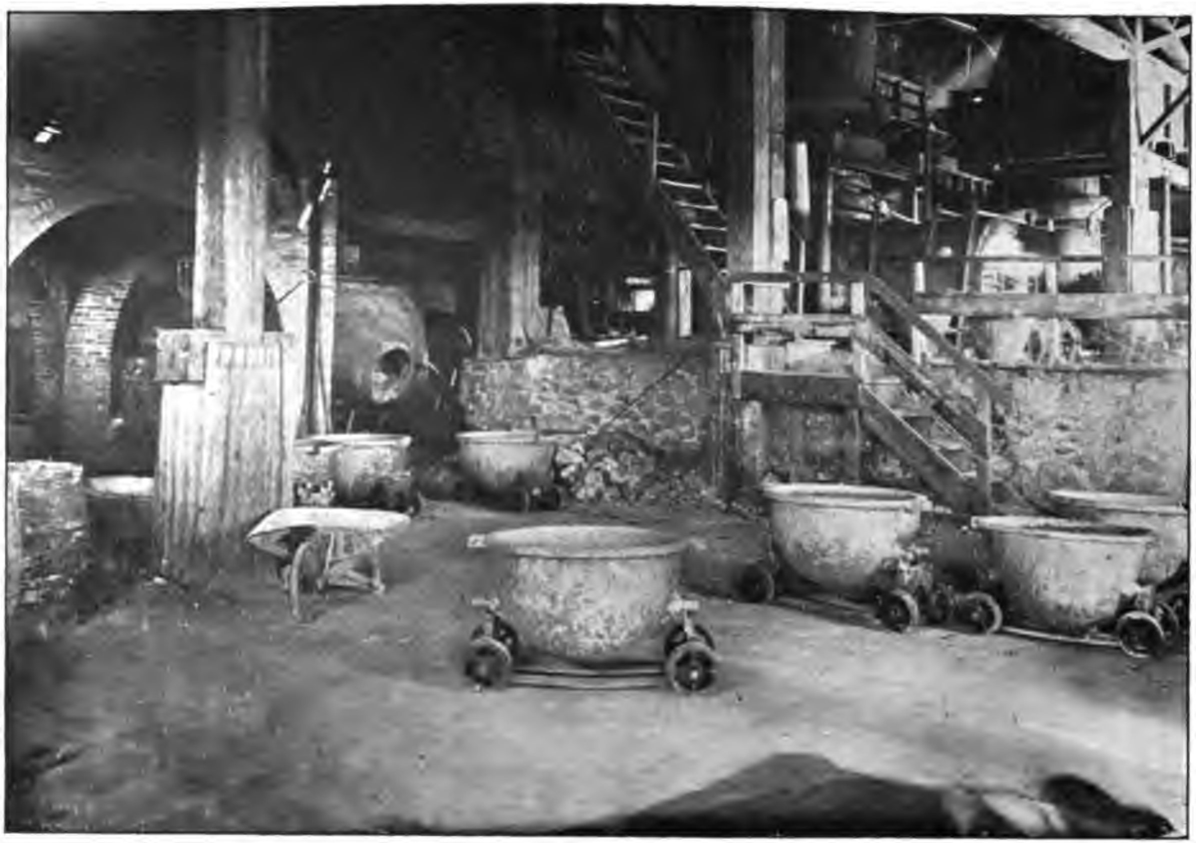


Roast yard of the Canadian Copper Co., at Copper Cliff, Ont.

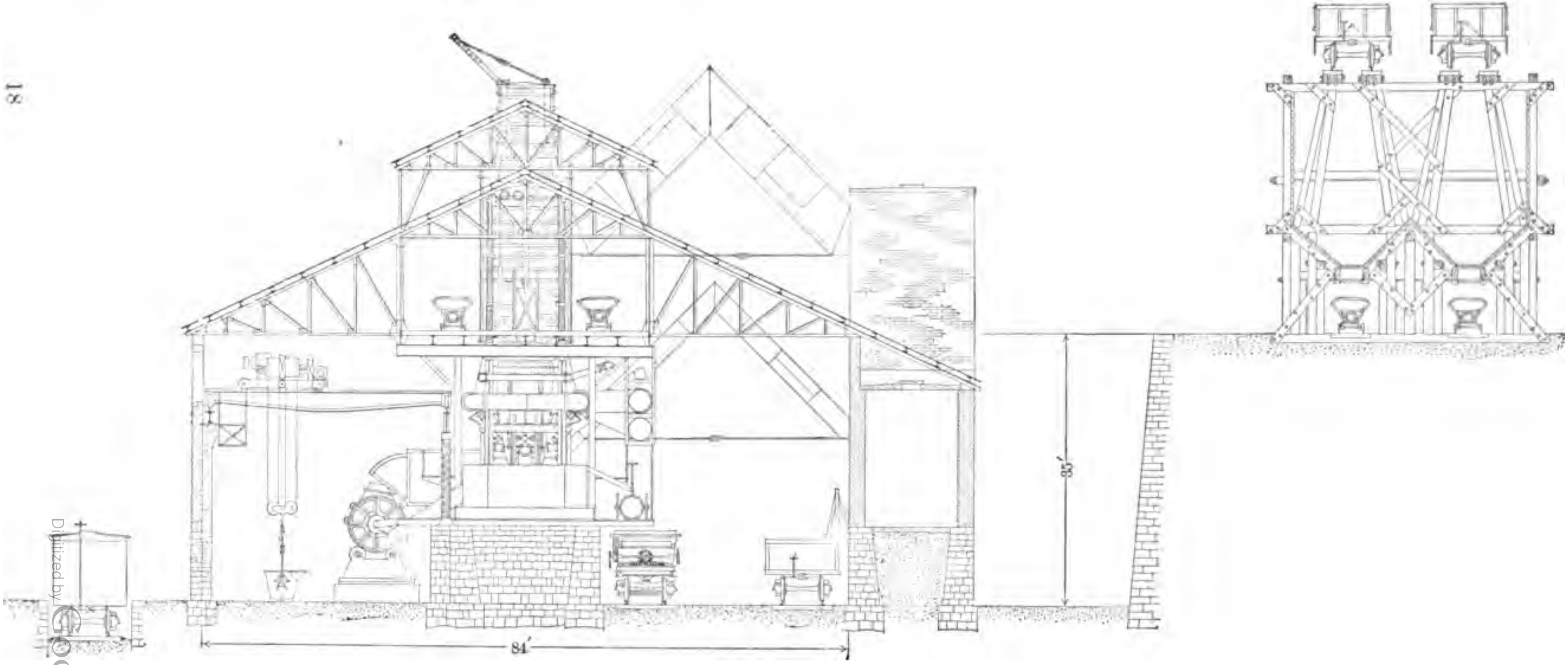
In the foreground the ore is being removed from a pile that is roasted; the next pile shows the wood already laid to receive the ore, while in the background are similar ore piles in various stages of preparation for roasting. In the distance some of the piles are already fired with dense fumes arising from them, while to the right is the elevated railroad which runs the whole length of the yard.

Roasting ore at main yard, Canadian Copper Co., at Copper Cliff, Ont.

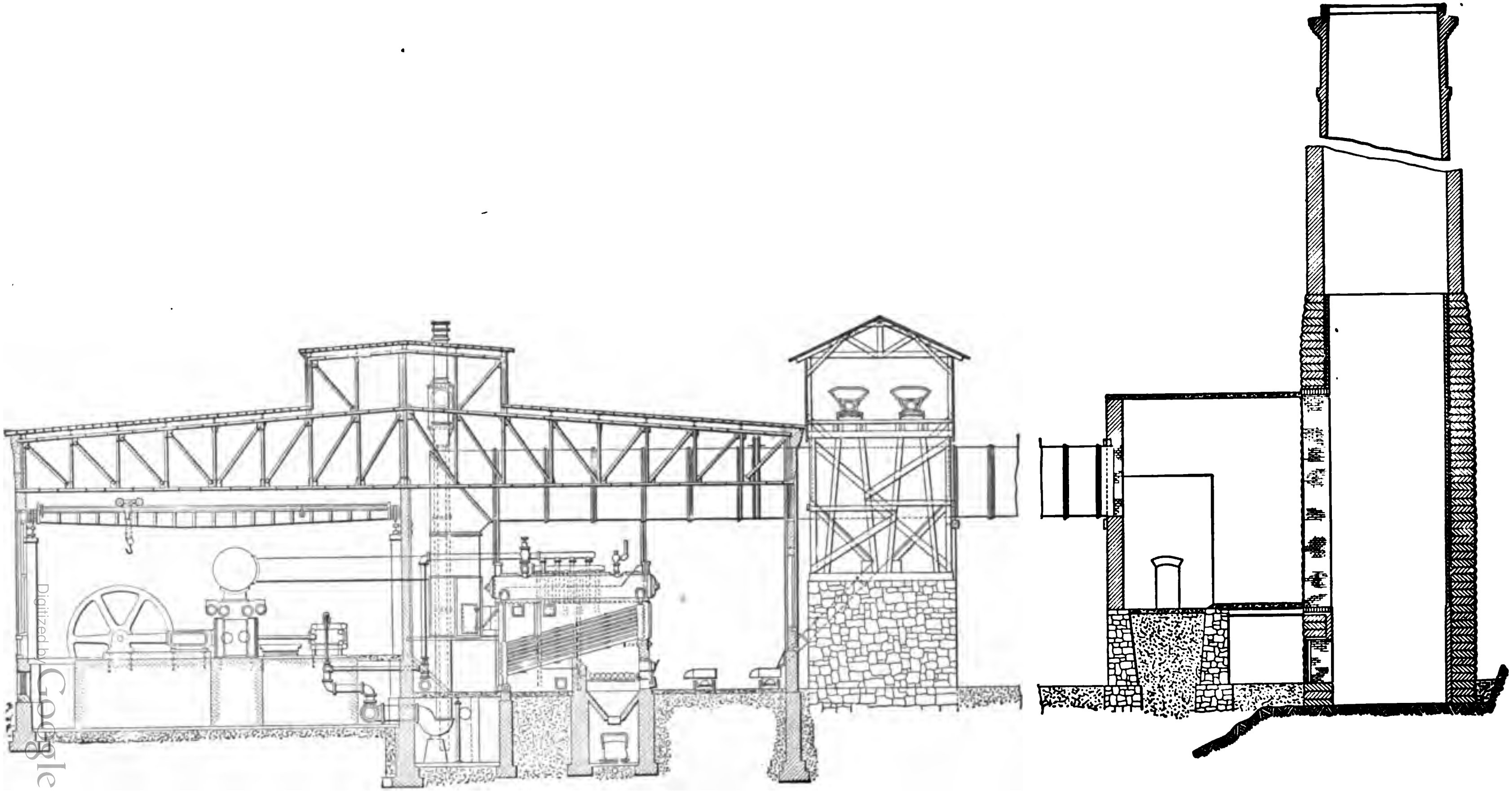
Elsie Mine (Lake Superior Power Co.).



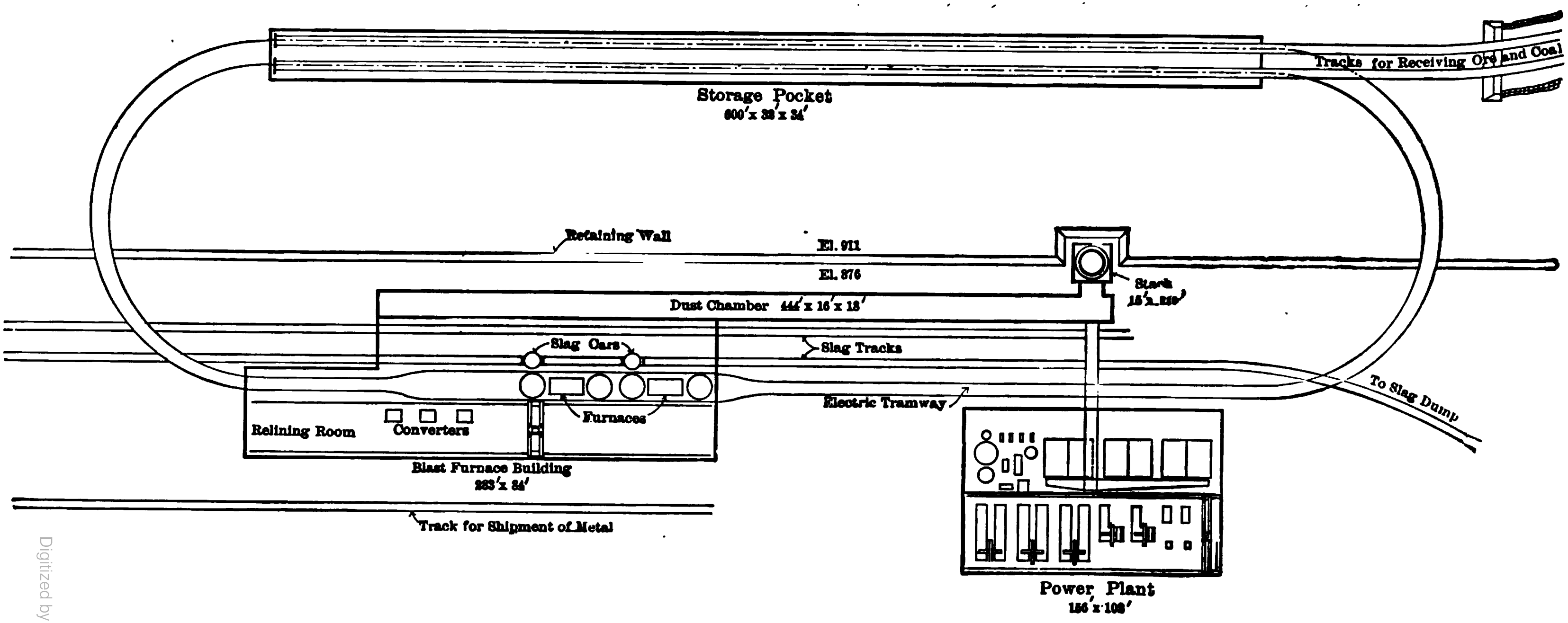
Interior of Smelter, Murray Mine, McKim Township.



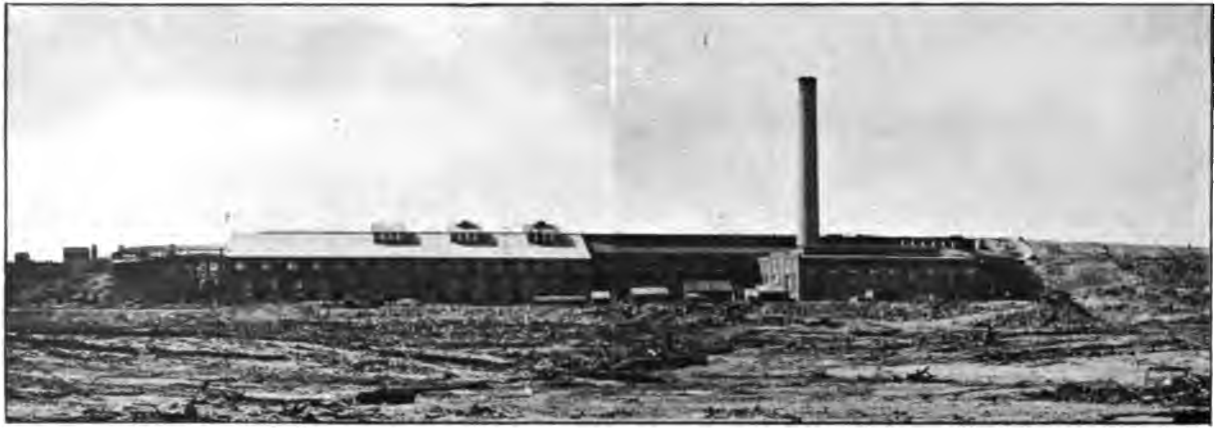
Cross Section of New Smelter of Canadian Copper Co., at Copper Cliff, Ont.



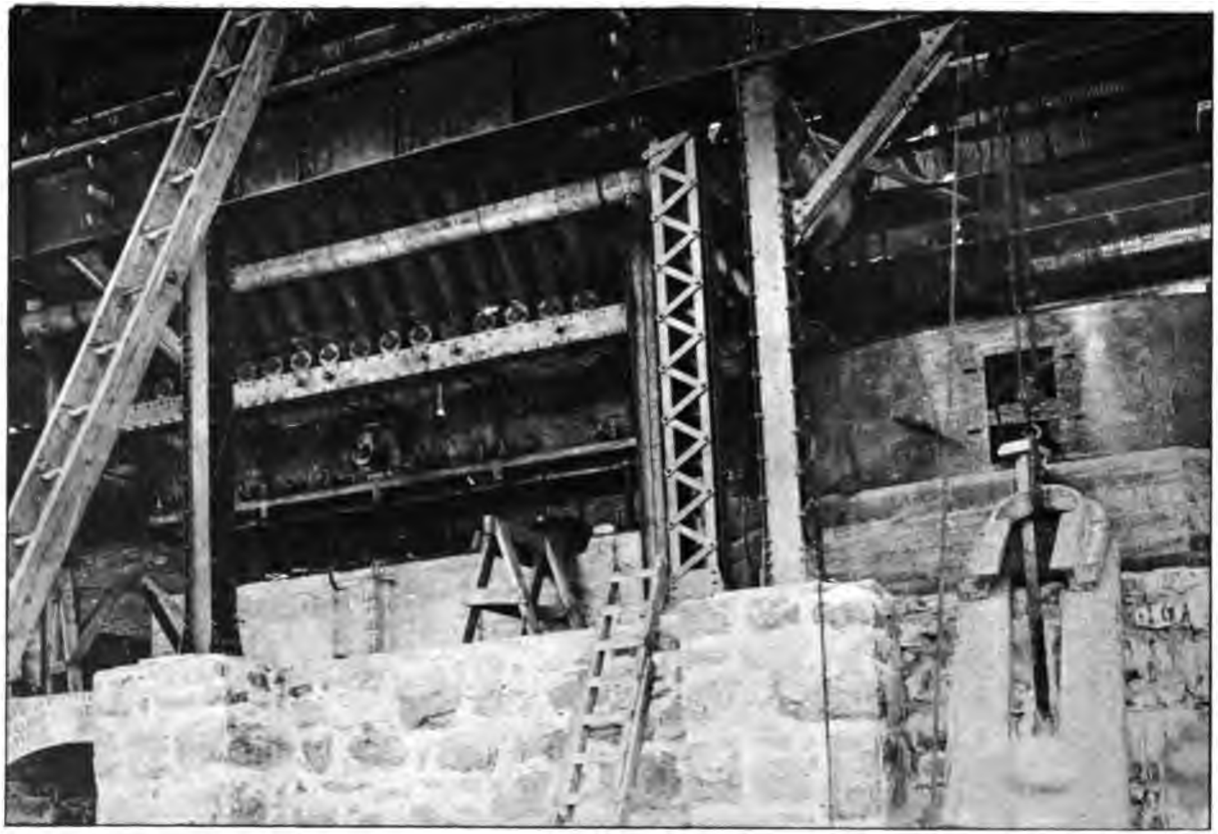
Section of Works at Copper Cliff.



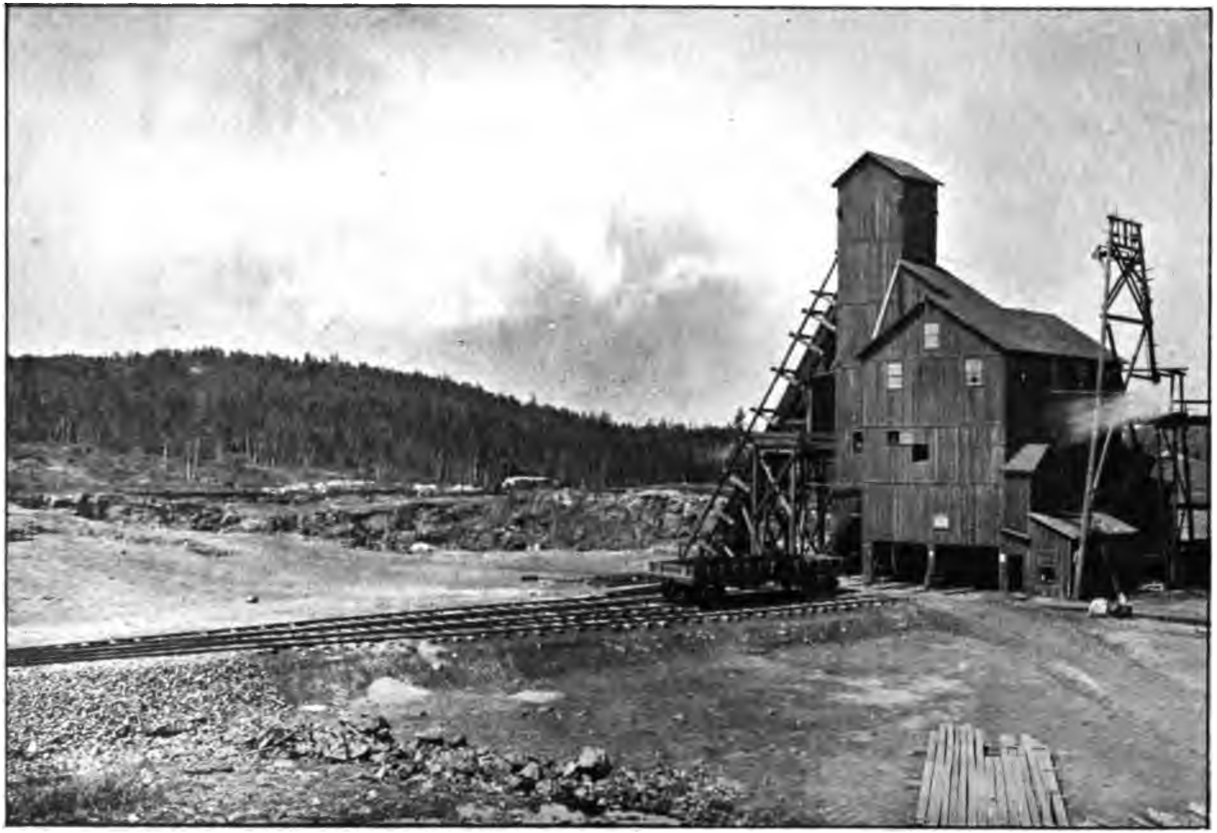
GROUND PLAN OF THE NEW SMELTER AND WORKS RECENTLY ERECTED BY THE CANADIAN COPPER CO., AT COPPER CLIFF, ONT.



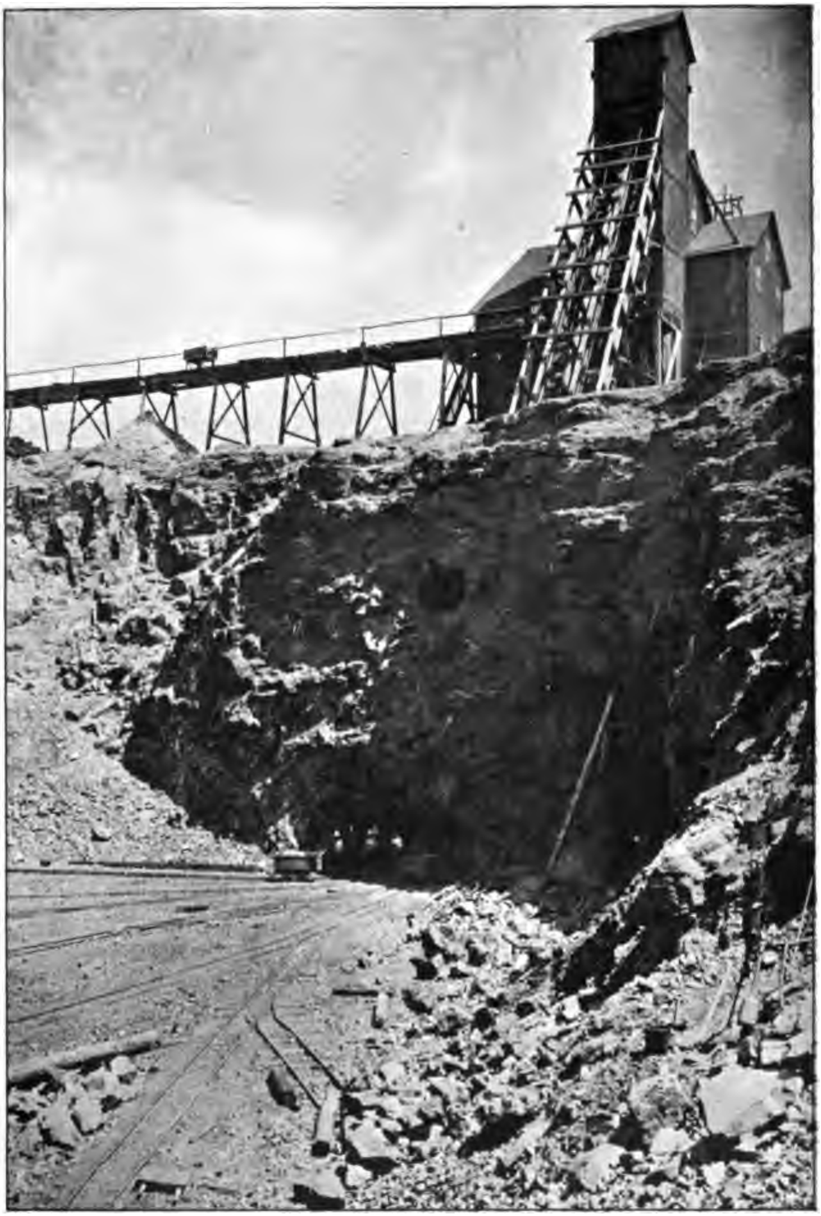
THE NEW SMELTER OF THE CANADIAN COPPER CO., AT COPPER CLIFF, ONT.
(Looking northwest.)



Interior of smelter in course of construction for the Canadian Copper Co., at Copper Cliff, Ont.
Showing the base of one of the new blast furnaces with forehearth partly completed.

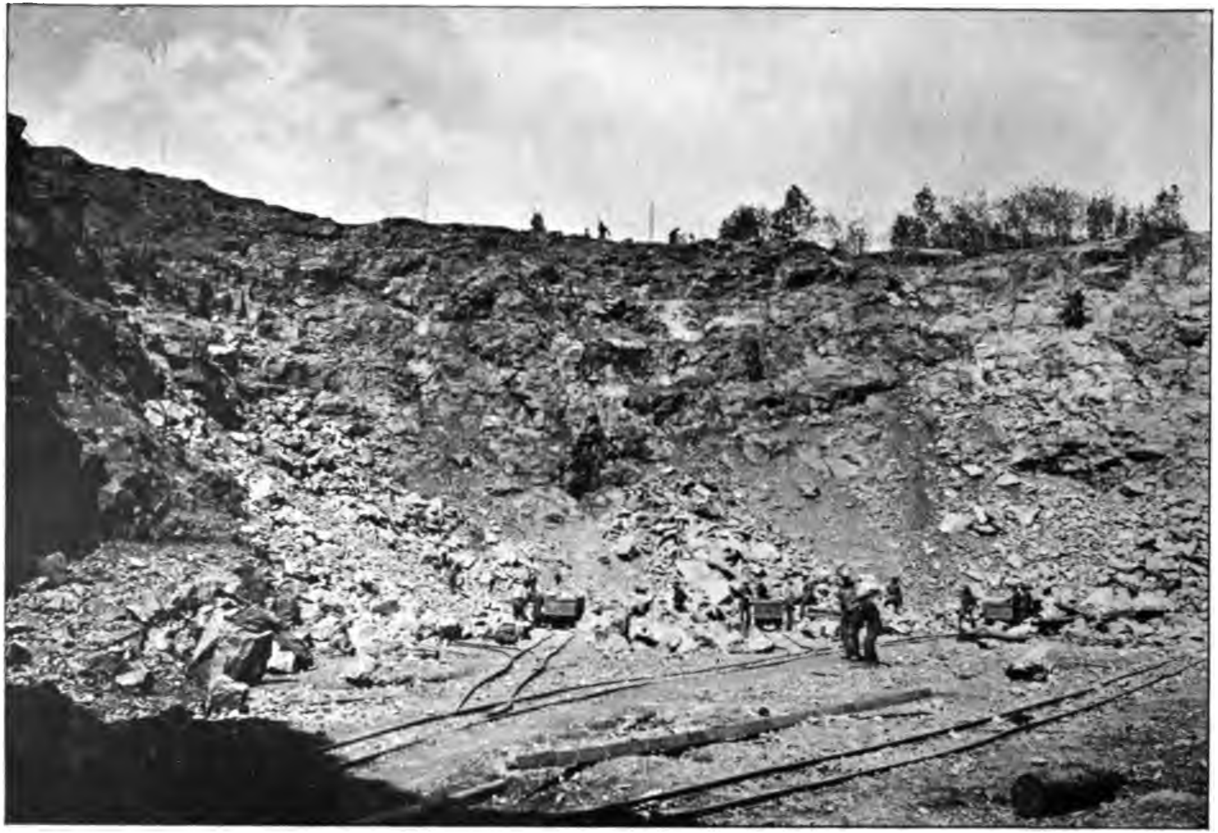


ROCK HOUSE AND MAIN OPEN PIT CREIGHTON MINE.

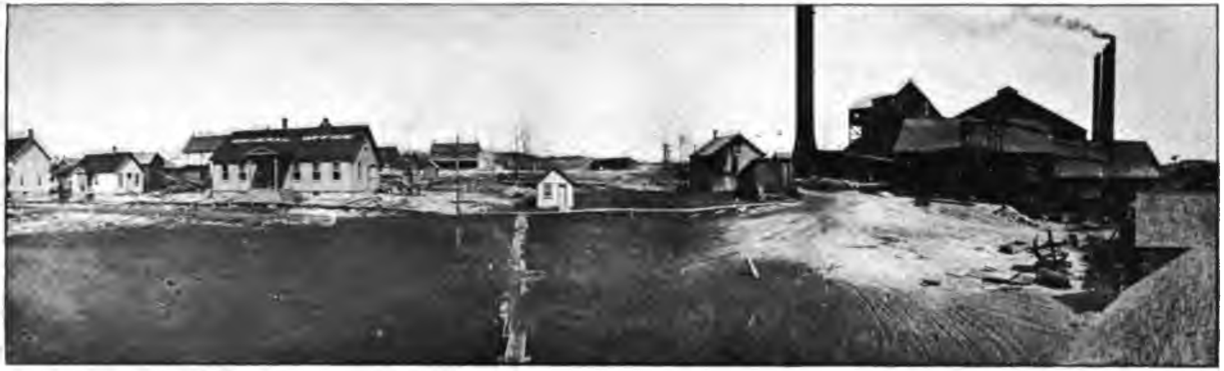


CREIGHTON MINE, CANADIAN COPPER CO.

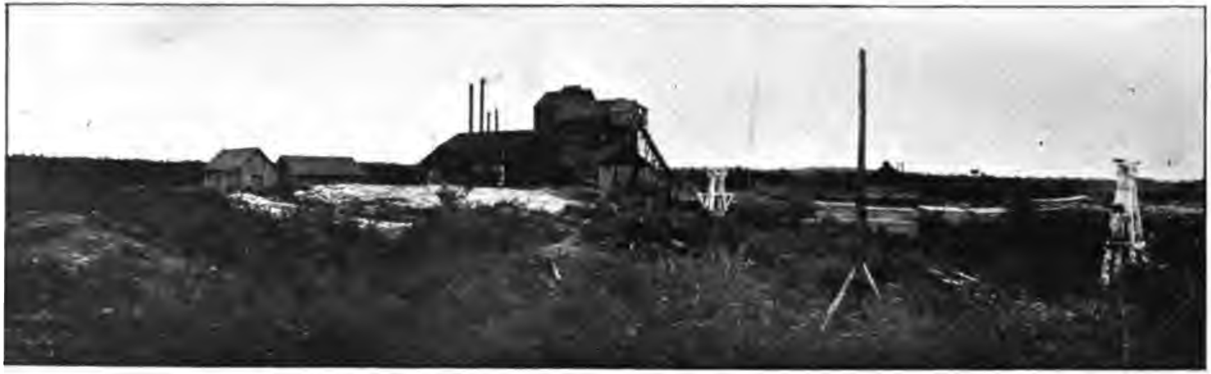
This view was taken from the side of the main pit looking S.S.E. and shows the methods of handling the ore.



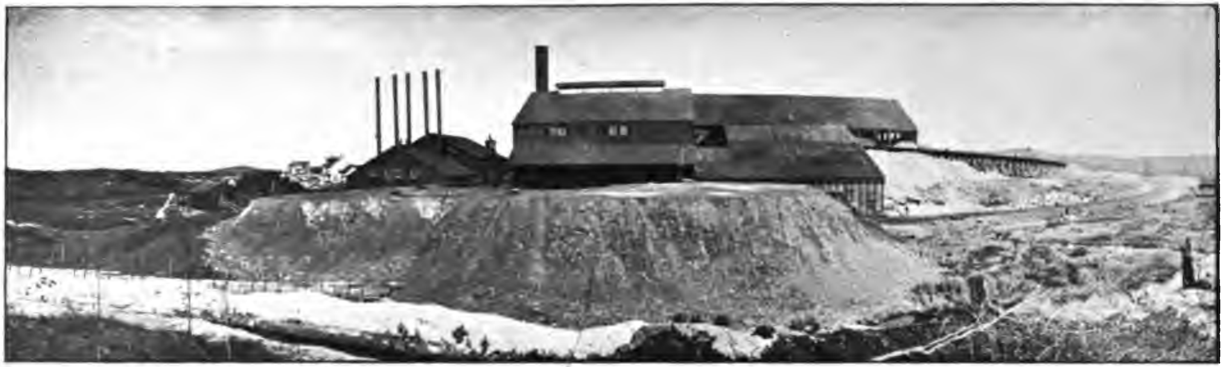
MAIN PIT OF THE CREIGHTON MINE, CANADIAN COPPER CO.
This illustrates methods of mining and the removal of the ore.



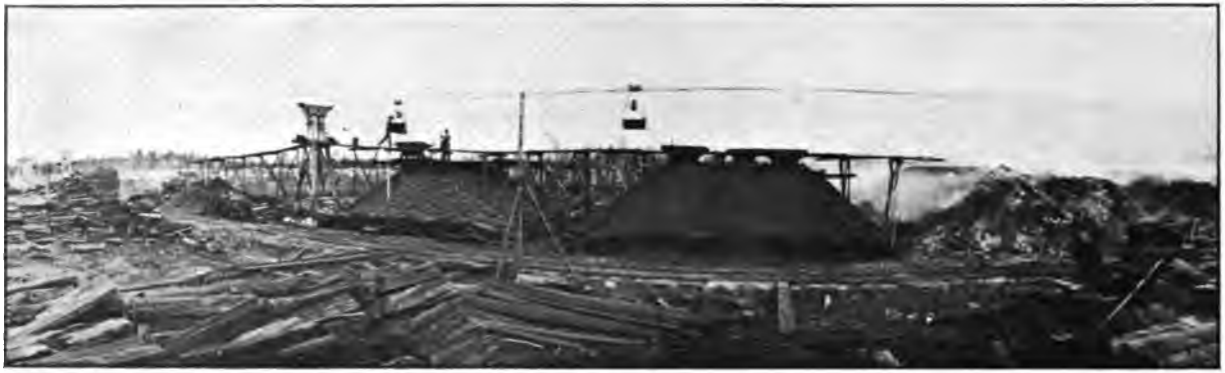
THE GENERAL OFFICES AND SMELTER OF THE MOND NICKEL COMPANY, NEAR VICTORIA MINES STATION.



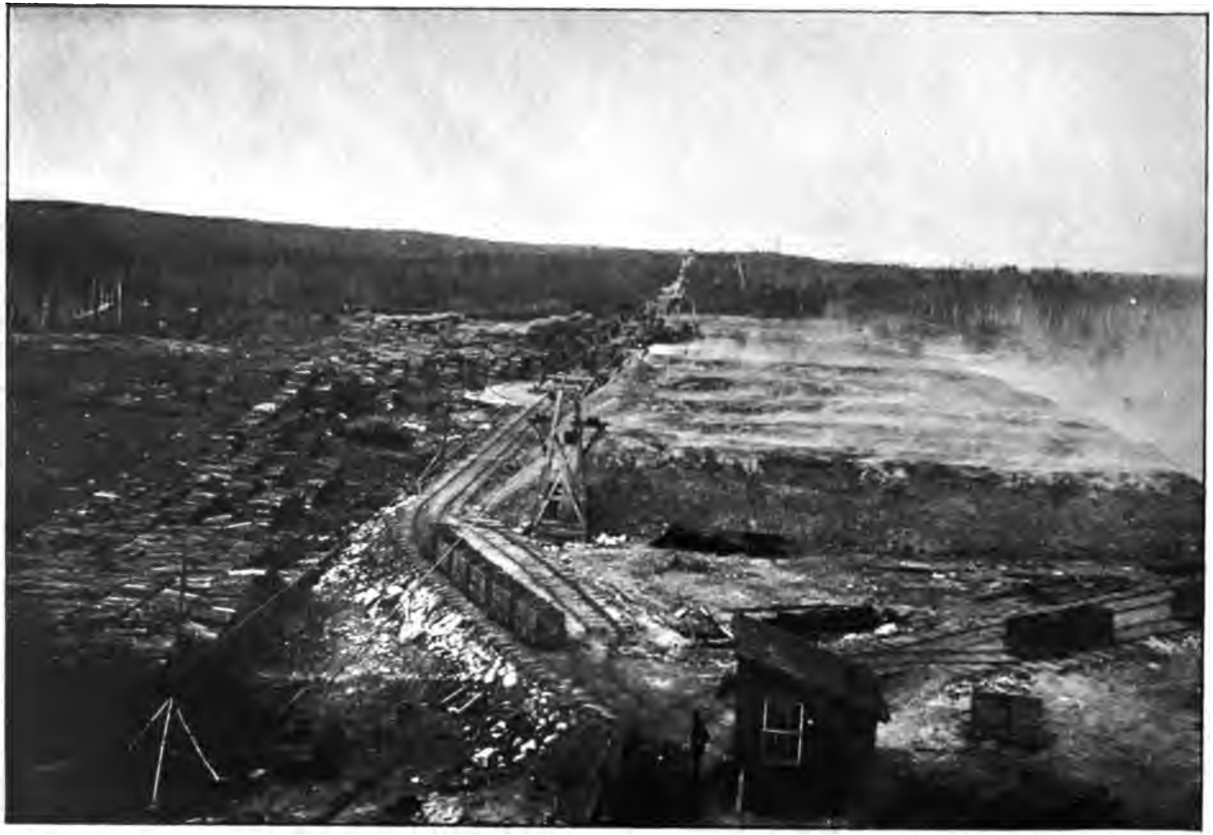
ROCK HOUSE OVER MAIN SHAFT AT VICTORIA MINES, MOND NICKEL CO.



THE SMELTER OF THE MOND NICKEL CO. AT VICTORIA MINES.
Slag dump in the foreground.

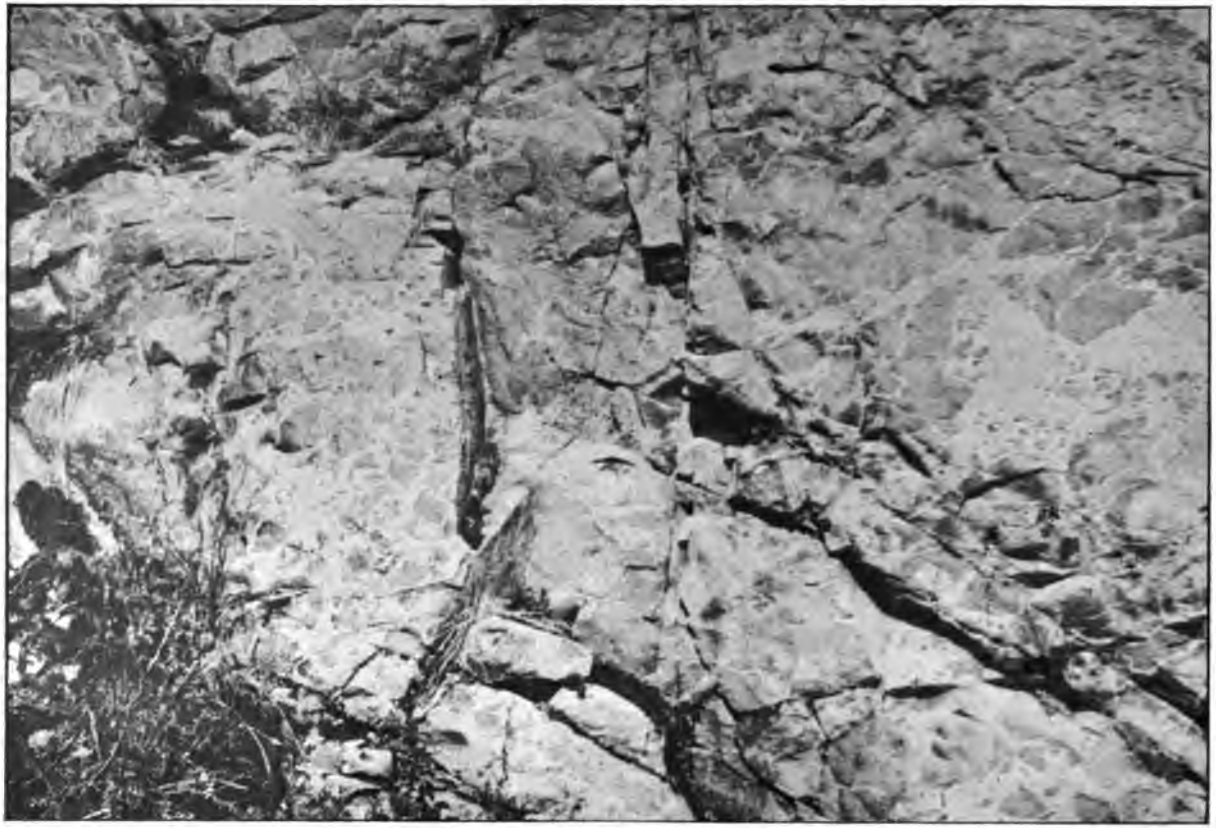


ROAST YARD AT VICTORIA MINES, MOND NICKEL CO., SHOWING METHOD OF CONSTRUCTION OF ROAST HEAPS.

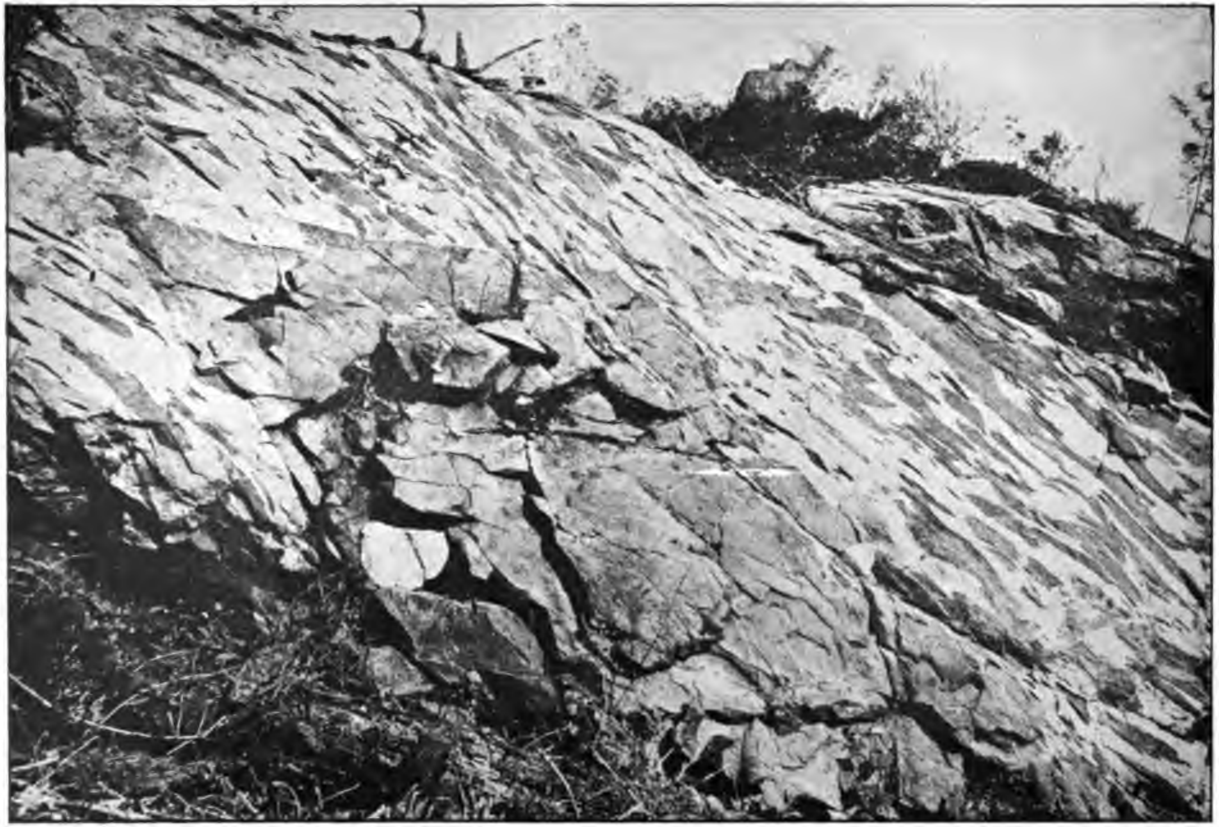


Roast Yard near Victoria Mines, Mond Nickel Co.

In the foreground is the weighhouse while in the distance can be seen the rock house over the main shaft.

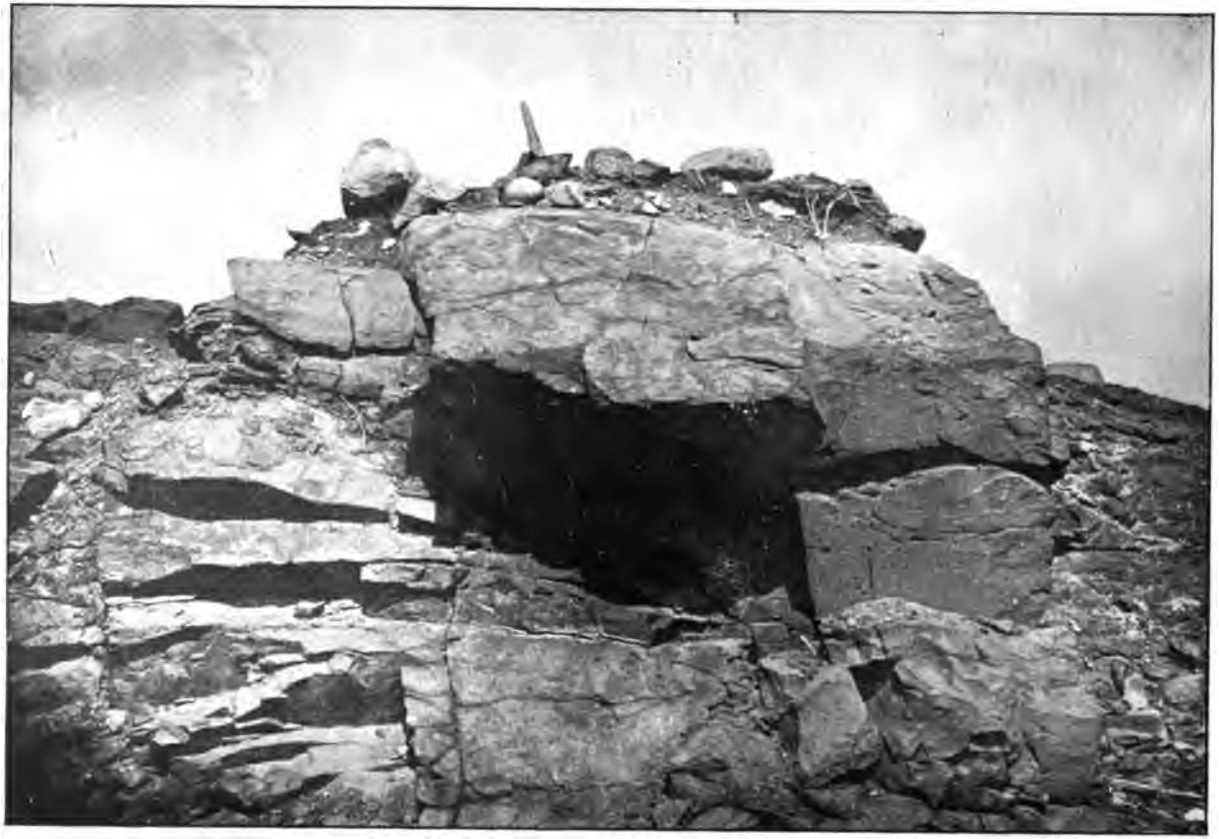


Breccia of Granite and Hornblende Schist, opposite Manager's House, Murray Mine.

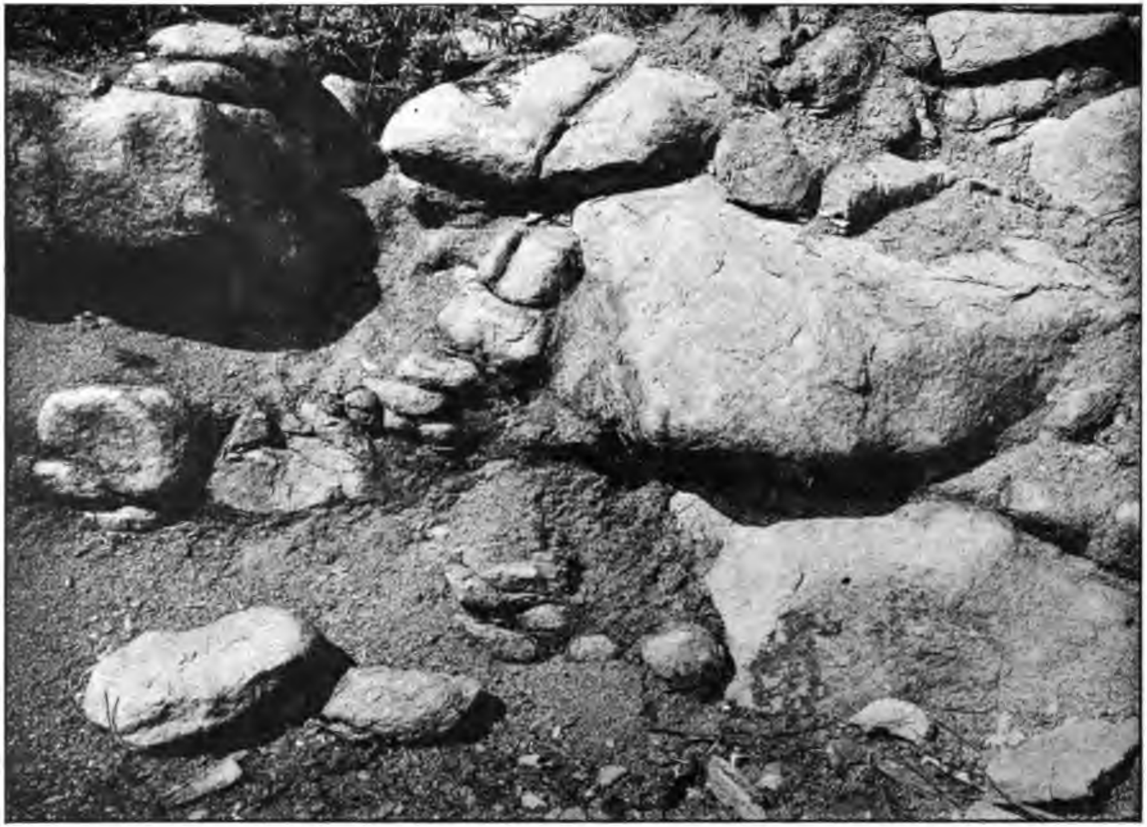


Breccia of Granite and Hornblende-Schist.

One quarter of a mile E. of Murray Mine, north of Canadian Pacific Railway.

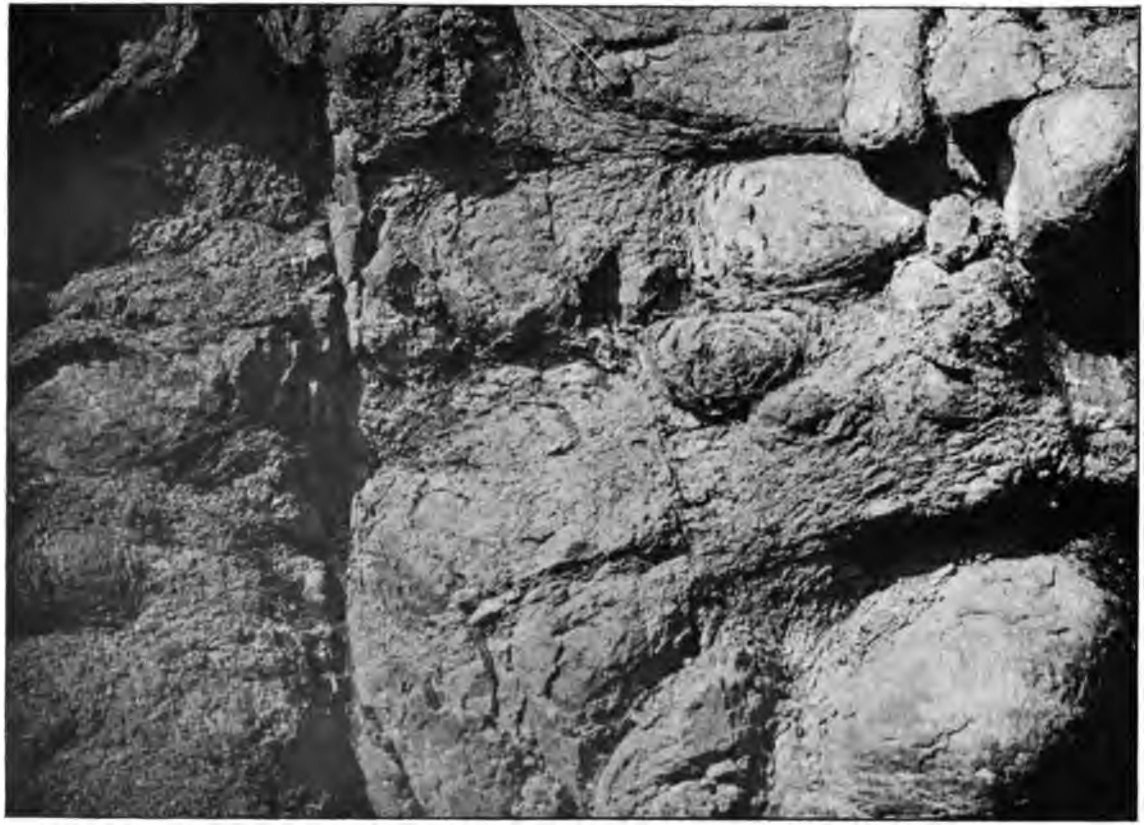


Dyke of olivine-diabase cutting ore body at Murray Mine.
Showing basaltic or columnar structure.



PORTION OF A DYKE OF OLIVINE-DIABASE.

Showing boulder-like masses due to spheroidal weathering and disintegration.



Portion of Dyke of Olivine-diabase.

The concretionary structure and spheroidal weathering shown are characteristic of this rock.

GEOLOGICAL SURVEY OF CANADA

ROBERT BELL, M.D., D.Sc. (CANTAB.), LL.D., F.R.S., I.S.O.

REPORT

ON THE

GEOLOGY OF A PORTION

OF

EASTERN ONTARIO

(*To accompany Map-sheet No. 119.*)

BY

R. W. ELLS, LL.D., F.R.S.C.

OTTAWA
PRINTED BY S. E. DAWSON, PRINTER TO THE KING'S
MOST EXCELLENT MAJESTY
1904

14—J

No. 790

To **ROBERT BELL**, M.D., LL.D., F.R.S., &c.,
Acting Director, Geological Survey of Canada.

SIR,—I beg to submit herewith a report on the geology and mineral resources of the area contained in Map-sheet, No. 119, of the Quebec and Ontario series. The map has been compiled by Mr. Joseph Keele, B.A. Sc., on the scale of four miles to the inch.

I have the honour to be, Sir,
Your obedient servant,

R. W. ELLS.

GEOLOGICAL SURVEY DEPARTMENT, OTTAWA,
May 1st, 1902

REPORT

ON THE

GEOLOGY OF PORTIONS OF THE COUNTIES

OF

RENFREW, ADDINGTON, FRONTENAC, LANARK AND CARLETON.

By R. W. Ells, LL.D., F.R.S.C.

Quebec and Ontario map-sheet.

This report is the second of a series, relating to the geology of the area traversed by the Ottawa river and contiguous to it, comprising in all four map-sheets, Nos. 121, 122, 119 and 120. The first of these has already appeared, and includes a somewhat detailed description of the principal geological features and mineral localities found in the district along the lower Ottawa, east of the Gatineau river. The present report refers more especially to the area entirely south of the Ottawa, being bounded on the north by a line extending west from the vicinity of Arnprior to a point a few miles north of Clear lake in the county of Renfrew, and on the south by a line east from Sharbot lake to a point a few miles south of Smiths Falls. The western line of the sheet joins that recently finished by Drs. Barlow and Adams known as the "Haliburton sheet." It embraces an area of 3,456 square miles.

Area included in report.

Compilation.

The compilation of the surveys has been well done by Mr. Joseph Keele, B.A.Sc., but there are certain areas difficult of access, and entirely unopened to settlement where a detailed examination can scarcely be carried out. These areas are however comparatively small, and are, as far as at present known, largely occupied by granite-gneiss, the presence of which, in large masses, forms a country generally of but little value either for agricultural or mineral resources.

Work previously done.

The area included in the present report comprises a considerable portion of the county of Renfrew, with parts of Lanark, Addington and Carleton. Portions of the district were traversed by different officers of the Geological Survey, some years ago, and different reports have been written on the included rocks, notably by Mr. Alexander Murray and Mr. H. G. Vennor. These will be referred to in the chapter on the crystalline rocks. Different traverses were also made across the area, by Mr. James Richardson, between the Ottawa river and Smiths Falls on the Rideau, extending as far as the town of Perth.

GEOLOGY.

Geological formations.

The geological formations found in the area comprised in this map-sheet may be briefly stated thus:—

Post-Tertiary.
Utica shales.
Trenton.
Black River.
Chazy shales and limestones.
Calciferous and Potsdam sandstone.
Mica, chlorite and hornblende schists and amphibolites, with some conglomerates.
Gneiss and crystalline limestones.
Granite, diorite, &c.
Granite-gneiss.

In the discussion of the several rock-formations, the Post-Tertiary deposits will be described in a later chapter.

PALÆOZOIC FORMATIONS.

Utica Shale.

Utica shale.

While the several members of the Palæozoic time are represented at a number of points throughout the Ottawa valley and the country adjacent to the south, these appear to show higher and higher elevations proceeding westward from the vicinity of Ottawa city. In this way the lowest beds deposited directly upon the crystalline rocks vary from the Potsdam sandstone, largely developed near Ottawa to the Upper Silurian at the northern end of Lake Temiskaming.

Thickness near Ottawa.

The Utica shale formation has a large development along portions of the lower Ottawa, where in the area to the south and east, there is probably a thickness of 300 to 400 feet. West of this, it has however not been recognized except at one locality on the slope of the mountain ridge south of Clear lake in the township of Sebastopol, Renfrew county.

Outcrop near Clear lake.

In 1896, these shales were found in a shallow ditch along the road up the mountain side, resting upon Trenton limestone which is exposed along the shore on the south-west side of the lake. The elevation above the water is about 90 feet, and the exposure is not well observed anywhere in the immediate vicinity except in the excavation. The elevation above sea-level is about 830 feet. As compared with the shales of the lower Ottawa basin, the difference in level of the two localities where these shales are found is, therefore, a little more than 600 feet.

Geology of Clear lake and vicinity.

The underlying rocks about Clear lake are gneisses and granites with occasional thin bands of crystalline limestone which form a prominent ridge rising to an elevation of about 600 feet above the lake at the base.

On the slope of the mountain along a road which ascends the hills about two miles west of this lake, debris of the shales was also observed resting upon the Trenton limestone, so that it is probable that a shallow outcrop of the shales extends at irregular intervals in this direction for several miles, though the rocks themselves are for the most part concealed by drift deposits. The shales at this place are of interest as showing that the rocks of the Palæozoic basin of the Ottawa at one time had a very wide development, and that they have been largely removed by the enormous denudation which has affected the whole area.

Fossils from Clear lake.

From the locality south of Clear lake, Mr. Wilson in 1896 made a collection of fossils which have been determined by Dr. H. M. Ami. Subsequent collections were made by Mr. L. M. Lambe of this department in 1897. Among these the following characteristic forms have been recognised.

Climacograptus, sp. indt. too imperfect for identification.
Crinoidal fragments.
Leptobolus insignis, Hall.
Leptobolus sp.
Lingula Progne, Billings.
Lingula curta, Hall.
Plectambonites sericea, Sowerby.
Dalmanella testudinaria, Dalman.
Zygospira modesta, Say.
Trocholites ammonicus, Emmons.

Endoceras proteiforme, Hall.
Serpulites dissolutus, Billings.
Triarthus Becki, Green, adult and larval forms.
Asaphus Canadensis, *Chapman*, (*A. latimarginatus*, Hall.)
Primitia Ulrichi, Jones.

TRENTON AND BLACK RIVER.

Trenton limestone.

The rocks of these formations are limestones. The areas of the former are limited and have been recognized at but two places in the map-sheet. Of these the most westerly is on the shores of Clear lake already referred to, where broad ledges of the limestone underlie the Utica shales on the south-west corner of the lake and extend for some distance westward. They are exposed for about one mile and a half along the shore or to the point where the road turns south up the mountain to the Opeongo road. This area is referred to in the report of Mr. Murray for the year 1853. The limestones can be traced southward from the lake road near the west end for a couple of hundred yards where they appear to rest upon the crystalline rocks. They contain the characteristic fossils of the formation, and are in a horizontal position, without evidence of faulting.

Trenton of Nepean and Huntley

The second area of Trenton is in the eastern part of the map-sheet in the townships of Nepean and Huntley. They here form a narrow belt extending from the vicinity of the Canadian Pacific railway at Stittsville to the vicinity of Antrim which is two miles south of Kinburn station on the Canada Atlantic railway. The rocks of the formation pass downward directly into the limestones of Black River age, and only the lower portion of the formation is apparently here represented, since the transitional form *receptaculites* is recognized at several points. In the eastern part of Huntley township the formation is somewhat thicker. The breadth of these rocks, as seen on the road south of Marathon on the line between Huntley and Fitzroy, is nearly three miles, though there is some difficulty in fixing the exact limits of the formation. South from Huntley post-office the breadth of the formation is a little greater, but over much of this township there are extensive deposits of clay, so that the area of the Trenton limestones is somewhat conjectural, being determined partly by scattered outcrops. The strata lie everywhere in nearly horizontal layers and where exposures occur their age is recognized by characteristic fossils.

Character of the formation.

Area east of Pakenham.

Another, but smaller area of these limestones is found on the crest of the ridge north of the Canadian Pacific railway between Pakenham and Snedden's crossing. They rest upon the Black River limestones and the exposures are visible on either side of the line between the townships of Ramsay and Pakenham, with an approximate length from east to west of about one mile and a half, by half to three fourths of a mile in breadth.

Black River limestone.

The Black River limestones have a much greater development. They occur at a number of places, sometimes as isolated outcrops of comparatively small extent, but in other places in the eastern part of the area these rocks can be traced continuously for over twenty miles.

Clear lake outlier.

Among the smaller areas may be mentioned the vicinity of Clear lake in Sebastopol township, where in the flat country to the west several good exposures can be seen. Among these is a point near to and on the road a short distance west of Clear lake post-office where these limestones form a low escarpment, resting against the crystalline rocks which show on the north. Further west on a road going south from a point about three miles west of the lake, good exposures of the massive limestones are seen near the base of the Brudenell ridge. The country from the lake westward in this direction is generally low and the formation apparently occupies a considerable area, the wester limit of which cannot be ascertained owing to the presence of drift sand. That it at one time extended over a much greater area than now exists, is shown by the finding of outcrops of similar rocks several miles further west on the road leading from Killaloo village to Brudenell post-office. The several occurrences of the Black River, Trenton and Utica in this area are all apparently of no great thickness, since they do not include in all more that a couple of hundred feet in vertical section.

Opeongo road.

On the Opeongo road which extends westward from the village of Dacre across the Brudenell hills, another isolated outcrop of these rocks is seen resting upon gneiss and crystalline limestone with an exposed area of about one mile in length by a fourth of a mile in breadth. The beds are well seen in a knoll about three miles east of the end of Clear lake near the point where the road is crossed by Constance creek. They occur for the most part north of the road, but there is a small outcrop on the Opeongo road also. No higher rocks were observed at this place.

Calabogie lake.

Further east, on the north side of Calabogie lake in the township of Bagot, along the road leading past the north side of the lake to the High Falls of the Madawaska river, there is another small area of the Black River limestone which also appears on the south side of the lake near Barryvale station and extends for a mile or more to the south of that place.

Ashdod outlier.

On the roads west of Ashdod station on the Kingston and Pembroke railway there is also another small outlier which occupies the crest of the ridge. At all these places the formation is easily recognized by the lithological character of the rock as well as by the contained fossils.

Areas near the Ottawa river.

The distribution of the Palæozoic formations along the Ottawa river has already been stated in a preceding report, since the greater number of these outliers is found in the map-sheet adjacent on the north. Along the Ottawa itself in the eastern part of the present map-sheet there is a large area of the same rocks extending to the south and forming a broad and well-defined basin. This is separated from the Ottawa below Arnprior by a prominent ridge of the crystalline rocks, consisting of granite, gneiss and limestone, which extends eastward to within about ten miles of Ottawa city, and divides the Palæozoic basin of the river from that which occupies portions of the townships of McNab, Fitzroy, Ramsay and Huntley, and thence extends south to the St. Lawrence.

In this large basin all the Palæozoic formations are represented from the Medina to the base of the Potsdam sandstone.

The outliers of the Trenton in this area have already been referred to. As to the remaining formations of the series these are frequently intimately associated through the agency of faults which traverse the area in several directions.

Black River, west of Arnprior.

South of Sand Point, five miles west of the town of Arnprior, the Chazy shales seen along the Ottawa are capped by the limestones of that formation, but the upper part of the ridge, rising to an elevation of about one hundred feet above the river, is composed of Black River limestone which is well seen on the south side of this ridge in broad ledges in places filled with the fossil *Teradium fibratum*. From a quarry on the south slope other characteristic fossils have also been obtained. South of this ridge the country is flat for some miles and clay-covered, but masses of red granite appear at intervals, so that the Palæozoic formations do not probably extend in this direction much beyond the limit of the ridge itself.

South of Arnprior.

South of Arnprior on the road to White lake which is about eight miles distant, the country for nearly five miles is largely clay-covered, but in the valley of the Madawaska the crystalline rocks show in the bed of the stream for a short distance above the town. The underlying rocks are, for the most part concealed, but masses of corals are found sometimes in the bed of the stream which indicate the probable presence of Black River limestones at no great distance. About five miles south of the town a somewhat prominent escarpment of these limestones comes to view and holds the characteristic fossils of the formation at many points. These limestones apparently rest upon the crystalline rocks of the Hastings series, from which they are probably separated by a fault extending west from Pakenham along the face of the ridge of crystalline rocks. The northern margin of this Black River area is also terminated by another fault which divides the limestones from the Calciferous formation. The western boundary is concealed by heavy deposits of marine clays and the relations to the underlying crystallines are not seen. North of this area and west of Arnprior for several miles are a number of scattered outliers of the Calciferous dolomite which rest upon the crystalline limestone and sometimes on granite, but these do not appear on the western margin of the Black River basin, so that it is possible the formation may also be terminated by faults on all sides. At Pakenham village the Black River limestones are well seen in the bed of the Mississippi river where they hold an abundance of corals such as *Columnaria Halli* with *Actinoceras Bigsbyi* and other forms characteristic of the formation.

Escarpment.

Limits of the Black River area.

Fossils.

These rocks are separated by a well marked fault from the Calciferous dolomite at this place, the latter showing in broad ledges along the south side of the river and passing down into the Potsdam sandstone a short distance to the east.

Fault.

In the townships of Fitzroy and Huntley several of the formations are exposed, ranging from the base of the Potsdam sandstone to the Trenton. The Black River limestone is conspicuous at a number of places and is affected by faults, some of which are important.

The northern limit of the basin of these rocks is apparently defined by the great fracture which extends north-west from near Fallowfield in Nepean township on the east, and which follows the southern flank of the ridge of crystalline rocks in the direction of Arnprior.

Northern limit of Black River limestone.

On or near this line of fault the Black River limestones are seen along the road which follows the town line between Huntley and March townships on lots 8 and 9, range I, of the latter, in contact with the ridge of crystalline rocks.

Faulted contacts.

Further west, just south from Carp river crossing, on the road south from Carp village a small outcrop is also seen, showing the continuance of the rocks of the same formation in this direction in close proximity to the underlying crystallines.

Fitzroy township.

Passing into the township of Fitzroy, similar Black River limestones are well exposed in an escarpment in which a quarry is located on lots 2 and 3, range IX, also near the ridge. The dip of the limestone at this place is N.W. < 10°, but it becomes reversed, a short distance to the west, to S.E. < 4°.

Limit of formation near Kinburn.

The western limit of this Black River basin is a short distance west of the road leading from Kinburn to Pakenham. The limestones are seen in the bed of a small brook a short distance north of the village of Antrim and are well exposed along the road south-east from that place between ranges III and IV; but the southern edge of the escarpment of these rocks is found a short distance south of this road, since the underlying Chazy is well exposed in a quarry on range III, lot 4, about 300 paces south of the road east from Antrim. The Chazy rocks do not apparently reach the road south from Marathon to Panmure which is along the town line of Huntley and Fitzroy, as the Black River rocks are exposed all along this road coming out from beneath the Trenton capping, about one mile or so north of Panmure corner.

Area in Huntley township.

From this place they are exposed in an apparently unbroken belt both to the east and west, in the latter direction reaching the village of Pakenham and eastward extending across Huntley into Goulbourn township where, on the town line, they have a breadth of rather more than two miles, capped by Trenton on the north of the Stittsville area and underlaid by the Chazy limestones on the south. The breadth of this Black River basin, with its overlying Trenton capping in the township of Huntley, is about six miles.

Pakenham to Almonte.

A third area of the Black River limestones is seen along the north side of the Mississippi river, extending eastward from Pakenham to the north of Almonte. It is affected by faults all along its northern margin which separate the limestones of the formation from the Potsdam sandstone on lots 14 to 20, ranges XI and XII, and in connection with this is a small outcrop of the crystalline rocks, consisting of granite, gray gneiss and limestone which appears on the line between these two ranges on lots 19 and 20. The southern margin is separated from the Calciferous by a fault at Pakenham village, but further east it is marked by the underlying Chazy limestones on the roads north of Snedden station on the Canadian Pacific railway and to the north of Almonte. The eastern limit of this area is apparently about lots 8 and 9, range XI, Huntley. Several faults are seen along the north side of the Mississippi river to the south-east of Pakenham village. Through-

Faults.

out the extent of these outliers and basins the characteristic fossils of the formation are readily recognized.

CHAZY.

Chazy shales and limestone.

Where possible the Chazy shales which represent the base of this formation have been separated from the limestones of the upper portion.

These have not been recognized at any of the isolated outliers in the western portion of the area comprised in map-sheet, No. 119, but they have a somewhat wide spread development in connection with the great Palæozoic basin of the Ottawa district.

Ottawa river near Berry's wharf.

Near the Ottawa river, in the township of Torbolton the lower shales appear on the south shore of the river nearly two miles east of Berry's wharf where they rest upon the Calciferous dolomites, the lowest beds consisting of a rather coarse gritty sandstone. The strata have a low dip of two to three degrees to the north, and are capped inland a short distance to the south by the limestones of the formation which form the crest of the ridge south of the wharf and extend southward to the depression occupied by Constance lake and creek. They here form the highest member of the Palæozoic series lying to the north-east of the ridge of crystalline rocks which extends from Arnprior to the township of March.

Contacts.

Area near Sand Point.

Further west the same succession of shales, capped by limestones, occurs to the east of Sand Point above the town of Arnprior, the relations of which will be pointed out in the report on the Ottawa river as represented on map-sheet No. 122.

Areas south of Ottawa river.

The principal areas of these rocks are found in the townships of Fitzroy, Ramsay, Huntley and Beckwith. In the first named township they apparently underlie the Black River basin on the west, and are in contact with the rocks of the northern ridge by a fault already described. They form a tongue extending south-east from the road leading to Pakenham from Antrim, where they separate the two areas of the Black River basin, on the west.

East of Pakenham they are exposed at several points along the north side of the Mississippi river, and at Almonte the shales at the base are seen in cuttings on the line of the Canadian Pacific railway, as well as on the north bank of the river; but in the northern part of the town these are overlaid by the Chazy limestone which is exposed as far north as the south line of Huntley township, where it passes beneath the Black River formation.

Shales at Appleton.

At Appleton also the shales are well seen on the north side of the Mississippi river along the roads, and thence east they continue into the township of Beckwith; where, although the surface is largely occupied by drift, they may be traced by occasional outcrops to the north of Blacks corners as far south as the line between ranges V and VI, including in this part of the basin the valley of the Jock river. The shales are also well exposed at Ashton village in the bed of this stream and they form a well-defined band in Goulbourn township extending east from this place to the road from Richmond to Perth, the contact with the overlying limestones being seen on the road south-west of Munster village at the crossing of the Jock and on the road near Dyers Hill, a short distance to the north-east of the crossing of the same stream.

Goulbourn.

Their contact with the underlying Calciferous is also well seen near Dyers Hill post-office and on the Jock river a short distance east of Ashton village. The outline of the formation is somewhat irregular, following, to some extent, the surface contours.

Faults.

In connection with the fault, which extends south-east from Pakenham across the southern part of the township of Huntley, the Chazy limestone is seen on the road south-west of Panmure, and is underlaid by the shales which are exposed in the bed of a brook on the line between ranges X and XI, lots 22 and 23. They here overlie the Calciferous dolomites which are cut off against the Black River formation by the fault in connection with the outcrop of the crystalline rocks of Huntley, already referred to. It is probable that another fault comes in on the north, which crosses in a south-west direction a short distance to the south of West Huntley church, on lot 15, range IX, since the Calciferous at this place is in close proximity to the Black River limestones, which form a somewhat prominent escarpment in this direction, extending westward to Panmure corner. This area in southern Huntley appears to be much affected by faulting, and the several formations are broken off abruptly at a number of points.

Huntley township.

East of West Huntley post-office this faulted area appears to die out and the relations of the Chazy and Black River formations are more regular. The limestones of the former, here comprise a somewhat extensive area, occupying the greater portion of the township of Ramsay north of the Mississippi river, the south-eastern part of Huntley, and the south-western portion of Goulbourn, with a breadth of about six miles on the line between Huntley and Goulbourn, and thence south; while the area extends eastward across the latter township to the vicinity of Richmond.

CALCIFEROUS AND POTSDAM.

Calciferous and Potsdam.

The Calciferous dolomite and Potsdam sandstone may here be described together since the former passes down into the latter through transition beds, the thickness of which ranges from 20 to 30 feet.

Arnprior.

The areas of these formations are entirely confined to the eastern portion of the map-sheet. The dolomites of Calciferous age are exposed at Arnprior, resting in patches on the crystalline limestones of that place. They are in contact with these by a fault in the western part of the town and a deposit of hæmatite occurs which was mined some years ago along the line of junction. Their extension west in the vicinity of the Bonnechère will be described in the report on that area, comprised in map sheet, No. 122.

Faults.

East of Arnprior in the district between the Canadian Pacific and Canada Atlantic railways the dolomites apparently occupy a triangular-shaped area extending eastward as far as the Mississippi river and underlying the Chazy and Black River of the Huntley basin. The exposures are few, and to the south-west the Calciferous is apparently bounded by a fault which divides it from the Black River, while to the north it rests upon the crystalline rocks, though probably a fault extends along the southern flank of this ridge, since there is a small outcrop of Potsdam sandstone on the crest of this ridge near the line between ranges X and XI, Fitzroy, on the road northeast from Kinburn, on lots 10 and 11. This place is at an elevation of 200 feet or more above the valley of the Carp at Kinburn, where Black River limestone occurs.

Potsdam north of Kinburn.

Torbolton and March.

In Torbolton and March townships the dolomites are exposed at a number of places. They form a continuous belt, extending south-east from Fitzroy village at the mouth of the Carp river, on the Ottawa, to the shores of the Ottawa river west of Britannia. They are well seen on the roads which cross the flat country in which Lake Constance is situated, and rest upon Potsdam sandstone to the south of March corners and thence west to Kilmaurs post office. The Potsdam sandstone terminates in this direction at the line between Fitzroy and Torbolton townships at about lot 12 of the former. The sandstones continue thence eastward along the northern flank of the ridge of crystalline rocks in a narrow belt, passing up into the dolomite in the township of March.

Faults.

South of this ridge, the sandstone and dolomite are brought to view by the fault in the southern part of the township of Huntley. They are exposed at intervals on ranges IX, X, XI and XII, extending from lot 12 to 22, their southern margin being terminated by a fault for the whole distance which separates these rocks from the Black River limestones.

Pakenham.

The southern margin of these formations rests upon the great area of crystalline rocks which occupy the principal portion of the area comprised in the map sheet. From Pakenham east, the lowest member f the Palæozoic formation is the Potsdam sandstone which is seen at frequent intervals as far as the shores of Mississippi lake. The sandstone belt is irregular in outline following the sinuosities of the underlying crystallines which evidently formed an old shore line at the commencement of Palæozoic time.

Mississippi lake.

From the upper end of Mississippi lake, through the western part of the township of Drummond, the sandstone is concealed and the dolomite rests upon the edges of the crystalline rocks; but approaching the town of Perth the sandstone, with an occasional mass of arkose or coarse conglomerate, again appears. To the south-west of Perth the sandstone extends through the southern part of the township of Bathurst almost to the shores of Christie lake, forming a belt from one to two miles in breadth. A southern arm of this Potsdam basin extends south from the Scotch Line post-office into North Burgess reaching as far in this direction as Black lake.

Rideau lake.

East of Perth the sandstone occupies the southern part of the township of North Elmsley and is well exposed around the lower end of Rideau lake, extending as far east along the Rideau river as Smith Falls. It passes upward into the Calciferous dolomite on all sides, the latter being the prevailing rock over the townships of Beckwith, Drummond, South Elmsley, Montague and thence out to the St. Lawrence at Prescott and Brockville.

Transition beds, fossils.

Over certain parts of this Calciferous area the denudation of these rocks has been such as to expose the underlying sandstones or transition beds at a number of points. It is from these transition strata, in which the sandstone becomes in places quite calcareous, that the best fossils are to be obtained, since through the process of weathering, the organisms, which are silicified, stand out from the layers and can be readily removed.

Conglomerates.

The lowest beds of the Potsdam in places are a somewhat coarse conglomerate or arkose, the pebbles of the crystalline rocks sometimes being large masses up to two feet in length. These are cemented by a coarse sandy and sometimes calcareous paste. While the sandstones as a rule are grayish or sometimes yellowish-gray; in places they are often coloured red through the presence of hematite. This sometimes assumes the form of ore deposits of this mineral, capable of being mined. These deposits are usually in the form of irregular pockets and vary in quality from impregnated sandstones, in which the siliceous matter predominates to an iron ore of considerable purity.

Iron ore.

The character of the sandstones and overlying formations in this district has been given in the earlier reports of the Geological Survey, much information being contained in the Geology of Canada, 1863, and in the several reports by Mr. H. G. Vennor from 1869 to 1874, as also in that by Mr. A. Murray, for 1853.

THE CRYSTALLINE ROCKS.

The crystalline rocks.

The work of the Survey on the crystalline rocks of this district dates back for nearly fifty years. The first exploration in the region was undertaken by Mr. A. Murray in 1852-53 or only nine years after the commencement of the work of the Geological Survey in Canada, in the area a short distance west of that contained in the present map-sheet. In that year a traverse was made of the district north from Kingston, by the chains of lakes which intersect the country in all directions, to Sharbot lake, and thence it was continued through the townships of Olden, Oso and Kennebec, the return journey being made by way of several rivers and lakes to the St. Lawrence at Belleville. The results of this field-work are given in the report for 1852-53. In this report the term Laurentian which had shortly before been devised by Sir W. E. Logan, to cover a large portion of the crystalline series in Canada, was employed.

Work by A. Murray.

The second exploration in the western part of the area was in 1865 and was carried out by Mr. Macfarlane. This was undertaken primarily with the object of ascertaining the value of certain deposits of hæmatite which had recently been reported as occurring in this portion of Ontario. Mr. Macfarlane's exploration led to important results, not only in the finding of iron deposits, but also as giving an expression of opinion as to the geological horizon of some portions of the crystalline rocks which had hitherto been classed under the head of Laurentian. Thus, in regard to the occurrence of certain of the granite masses which had previously been regarded as altered or metamorphosed sediments, it is stated that 'It is not in all cases possible, without a careful study of their attitude, to say whether these granite-like masses are intrusive rocks; as remarked on page 587 of the Geology of

Mr. T. Macfarlane.

Canada, 1863', "the coarse grained granitoid and porphyritic varieties (of the Laurentian Gneiss) which often form mountain masses, sometimes have, at first sight, but little of the aspect of stratified rocks, and might be taken for intrusive granites." This remark arose doubtless from the expression of the theory as put forth in the Geology of Canada, 1863, that the Laurentian represented the first great development of sedimentary rocks in a highly altered condition.

Sir W. E. Logan's views.

In describing certain of the rock-formations there met with, especially as regards intercalated schistose conglomerates, which have since been recognized as an integral portion of the Hastings series at various points, Mr. Macfarlane also calls attention to the fact that they are not unlike some of the Huronian rocks; and in connection with this Sir W. E. Logan remarks that 'the rocks of Marmora and Madoc and other townships in Hastings, have been provisionally classed with the Laurentian series, with which they appear to be conformable, and in common with which they hold Eozoon Canadense, in which however the canals and interspaces of the fossil are filled with carbonate of lime, instead of any of the silicates filling them in other parts. These Hastings rocks may be a higher portion of the Lower Laurentian series than we have met with elsewhere. It is not to be inferred from the presence in them of a schistose conglomerate that therefore they are Huronian. Some may be disposed to compare the Hastings rocks with the metamorphic Lower Silurian of Eastern Canada, but the micaceous limestones of Hastings more closely resemble the micaceous limestones which run from Eastern Canada into Vermont, on the east side of the Green Mountains, and which, from their fossils, are known to be Devonian.'*

The work of Mr. Macfarlane was taken up in the following year by Mr. H. G. Vennor, who in, 1866, began a detailed study of the rock-formations in this district and continued the work of mapping their distribution for some years. The first portion of this work was confined also to the area south of the district comprised in this map-sheet, and included the structure of the several groups of strata which had now become regularly known as the Hastings series, from the fact of their first being studied in the county of Hastings. This work was largely commenced from the economic standpoint, in order to ascertain the horizons at which certain deposits of the metals, in which the gold of Madoc and Marmora, which had recently come to light, formed an important element. In so far therefore as the first few years of Vennor's work is concerned, it may be regarded as beyond the scope of this report, but as this exploration gradually progressed eastward it reached the county of Renfrew, and finally the Ottawa river, so that for several years Vennor's labours were confined to the area now under discussion. As in the course of this series of examinations the rock formations first encountered were found to be traceable across the entire distance from Hastings county to the Ottawa, the relations found in the one portion of the field may be considered as to a large extent applicable to the whole. Subsequently this series of explorations was continued across the Ottawa and extended northward for about ninety miles along the Gatineau river, and the other streams to the east of this, it it reached the great anorthosite masses to the north of the city of Montreal.

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* Rep. Geol. Survey. 1866, page 93.

Work by Mr. H. G. Vennor.

As the result of the study of these rocks by Vennor for several years, they were arranged under three heads, in the Report for 1866-69 styled respectively Divisions A, B and C. In the first was placed a great mass of reddish syenitic and granitic gneiss, portions of which were without apparent stratification, and were held to form the base of the series. Above this was a series of grayish and flesh-coloured gneiss, passing into a mica schist, with some diorite, above which was included several hundred feet of crystalline limestone, sometimes magnesian, and in which, at several places, the remains of Eozoon were found.

The second division consisted of hornblende and pyroxenic rocks with schists of various kinds, also including diorites and beds of magnetite; while the rocks of Div. C, comprised crystalline magnesian limestones, mica slates, quartzites, &c., with some conglomerates. The lithological differences of certain portions of these divisions from the rocks which were hitherto regarded as Lower Laurentian, were at the same time pointed out.

Two divisions.

In the report for 1870–71 these divisions were condensed and the statement was made as regards their probable horizons that those of division A might be classed as Laurentian, while divisions B and C were regarded as probably Huronian.

Vennor's conclusions, 1876-77.

The results of Vennor's explorations appeared in several annual reports, extending down to 1876–77. In this last his work north of the Ottawa is also described and the connection was made between the rocks of the Hastings and the Grenville series, the one being regarded as the equivalent of the other. From the fact that the views as to the structure of the Laurentian still maintained the presence of an upper series of Anorthosites, at that time considered as an unconformably overlying series of altered sedimentary rocks, which were supposed to cap the Grenville and Hastings series at several points, or to constitute a portion of the Hastings series to the south of the Ottawa river, it became necessary, in order to support the theory already advanced, to place all these rocks, beneath the Anorthosites, or in the Lower Laurentian; and, in the last of the reports alluded to, Vennor divides the crystalline rocks of the Ottawa district into two grand divisions, viz., 1st. a great gneissic and syenite series without limestones, and 2nd., a thinner gneissic series with labradorites and limestones, which were capped by the Lower Silurian sediments comprising the Potsdam sandstone and other formations to the top of the Trenton.

Eozoon Canadense.

One of the most important factors leading to the change of opinion on the part of Vennor in placing the rocks, which he was at first inclined to regard as Huronian, in the Lower Laurentian, was the finding of Eozoon in certain of the limestones which he had assigned to division C; and in fact, so long as the contention was maintained that the presence of this fossil was indicative of a Laurentian horizon, no other scheme of classification was admissable.

Dr. Selwyn's Views, 1877-78.

Although the igneous nature of the Anorthosites was maintained by several of the leading geologists both in America and Europe for many years prior to this work in Canada, it was not till after this final report of Vennor's had been published, that this view was adopted by the head of the Canadian Survey. Thus in 1877-78, Dr. Selwyn, from a study of the work of Vennor, as contained in his field notes on the area north of Montreal for that year, expressed the view that, if these observations were correctly made, the Anorthosites should be removed from the position they had so long held as the upper altered sedimentary portion of the Laurentian, and should be regarded, not as altered sediments, but as igneous rocks of later date than the Grenville and Hastings series with which they were associated. So much was Dr. Selwyn impressed with this new view of the structure, after examination of the facts then available, that he reconstructed the scheme of formations for the lower crystalline rocks, by assigning to the Laurentian proper only the lowest series of gneiss, granite and syenite which showed no trace of sedimentation, while the sedimentary gneiss, limestone, quartzite and schists, which constituted the greater portion of the Grenville and Hastings series, was assigned to the Huronian, and made the equivalents of the crystalline rocks of the eastern townships of Quebec, a series which had been long known as the "altered Quebec group."'

Modification of Selwyn's views, 1881-82.

The view that the Anorthosites were originally of sedimentary origin doubtless arose largely from the fact that a gneissic or foliated structure was visible in these rocks at many points; but though this change of view was advocated by the then Director in 1878, so important were the issues involved considered to be, that the facts obtained were not at that time regarded by him as sufficient to warrant altogether an official change of opinion, in view apparently of the supposed Laurentian horizon of Eozoon: and in the scheme of nomenclature, put forward in 1881-82, a return was made to the original scheme of classification, the Laurentian being again divided into a lower, middle and upper portion, succeeded upward by the Huronian.

Work by Dr. Adams.

Later the work of Dr. Adams on the Anorthosite areas north of Montreal conclusively showed that these might be regarded as unmistakably intrusive masses of later date than the rocks of the Grenville series with which they were associated. These rocks were thereupon definitely removed from their position as the upper member of the Laurentian system and the rocks of this series were then arranged under two heads, viz., a lower series comprising the lower division of Vennor, and an upper series of gneiss and limestone with quartzites, &c., which were embodied in the Grenville and Hastings series.

Grenville and Hastings series practically the same.

The similarity of these two series (the Hastings and Grenville) and their equivalence in point of time was pointed out by Vennor as far back as 1876. In the report for that year he also regards the Anorthosites as constituting the upper member of the Laurentian, but expresses doubt as to whether this is the correct view of the structure. Assuming it to be so however for the present, he concluded that all the underlying rocks, including the lower gneiss and upper series of gneiss and limestones must be regarded as Lower Laurentian, the term middle Laurentian thus being eliminated from the nomenclature of the subject.

Probably Huronian.

In the mean time the original contention, that the rocks of the Hastings series might be Huronian was still maintained by some observers. The great resemblance of many of the rocks which made up the series to certain rocks found in New Brunswick and in eastern Quebec, which had been regarded and described in the reports of the former province as Huronian, was very marked, and their study under the microscope showed that, as compared with the rocks of the lower granite gneiss, the two were largely different in origin; since, while all the evidence as regards the latter went to prove that large portions were really altered igneous rocks, without any trace of sedimentary structure, in the case of the upper series the evidences of sedimentation were very often apparent. In both series, however, large masses of rocks, similar in character to those of the lower series, are associated; and in many cases, where their relations could be clearly made out, it was recognized that the limestones and associated gneiss, with certain of the schistose portions and conglomerates, were unconformable upon the lower gneiss, and that the latter had invaded the former, after their deposition when presumably in a plastic condition.

Dr. Sterry Hunt's views, 1878.

In 1878 Dr. Sterry Hunt, in his report to the Second Geological Survey of Pennsylvania, reviewed very exhaustively the whole subject of the crystalline rocks of the United States and Canada; and in discussing the question of the rocks of the Hastings series places them in the Huronian system, but does not recognize their equivalence with the Grenville series, which he still regarded as a member of the Laurentian. This view of Hunt's is apparently due to the fact that he still regarded the Anorthosites as altered sediments which, however, he separates from the Laurentian proper and describes under the head of Norian, but as beneath the Huronian proper. The Hastings series in this case was placed in the same general group as the rocks of the altered Quebec series, the Montalban or mica schist series of the White Mountains, and the lower Taconic of Emmons as occurring in the state of Vermont.

Logan's Grenville limestones.

The peculiar arrangement of the crystalline limestones of the Grenville series, as originally laid down by Logan in his manuscript map of the Grenville district, north of the Ottawa river, in which area four and possibly five, distinct horizons of these calcareous rocks were supposed to exist, separated by thousands of feet of reddish orthoclase gneiss, led to what is now regarded as an incorrect interpretation on the part of Vennor of the structure of the similar rocks west of that river. Thus, in the study of the rocks of the Hastings group, Vennor, recognizing that the two series were one and the same in great part, since the limestones and associated strata of the former were readily to be traced into the similar divisions north of the Ottawa from the county of Hastings, endeavoured to parallel the several bands found in the western area with those which had been located in the Grenville district; but in this attempt much difficulty was experienced. The tracing of these limestone bands for long distances was not, in all cases found to be practicable; for, while certain of them could be followed for some miles, in other cases their continuity was affected by what appeared to be large intrusive masses of granite, or sometimes diorite, which sometimes abruptly terminated the bands or, in the case of the granites, deflected them from their regular course.

Work of 1891.

In 1891 the writer began the detailed examination of the area north of the Ottawa, in the typical district where the rocks of the Grenville series were first studied; and, in the course of the next three years, carried these explorations along the Ottawa river as far west as the Rapides des Joachim, about fifty miles west of the town of Pembroke, an area comprised in map-sheets Nos. 121 and 122. Passing thence to the study of the district south of that river, the examination of these rocks was continued southward and westward along the Bonnechere, the Madawaska and the Mississippi rivers, and over the intermediate country, comprised in the sheet more immediately under discussion known as No. 119. At the same time the area embraced in the map-sheet adjoining on the west, which comprises a portion of the district first studied by Vennor, was undertaken by Messrs. Adams and Barlow. The study of the rocks in these adjacent areas has since been consecutively carried out, so that the unravelling of the structure of this complicated group of formations, pertaining to the crystalline rocks in this part of the province, has now reached a fairly satisfactory conclusion. It may be stated that the views reached by the several workers in these fields are in perfect harmony, as regards all the important points of structure observed, the conditions found in the two areas being practically the same. Certain minor matters of detail yet remain to be completed, but it is hoped that the true relations of the Hastings and Grenville series to each other have been ascertained, as also their relations to the great underlying granite-gneiss series, which has for some years been held to represent the fundamental rocks of the district, and regarded as constituting what may be styled the Laurentian proper. Some of these results have already been given to the scientific world in several papers presented to the Geological Society of America and elsewhere.

Work of Drs. Adams and Barlow.

The Laurentian proper.

Present arrangement of crystalline rock.

In discussing the geological structure of the area comprised in these map-sheets it must be premised that a close and detailed study of every portion is not possible. Large portions of the district are as yet not opened up by roads, and even woodpaths, which at one time existed, have now become practically impassible owing to the forest growth. Often the underlying rocks are concealed by large deposits of sand and loam, so that the extension of certain bands which are observed at widely separated intervals must be largely conjectural.

The rocks in the area now being considered may be roughly divided into several groups as follows.

1st. Granite-gneiss and syenite which apparently represent the oldest series upon which the others rest.

2nd. Gneiss, often grayish or reddish-gray, sometimes highly quartzose and garnetiferous, but of various shades of colour, certain portions of which pass upward into limestones.

3rd. Amphibolites with schists, sometimes micaceous, sparkling and glistening, often containing garnets, at other times chloritic, hornblendic or dolomitic, with altered slates and true conglomerates and limestones.

4th. Granites and diorites, some of which are clearly intrusive and newer than the rocks which they penetrate.

THE UNDERLYING GRANITE-GNEISS SERIES.

The granite-gneiss.

In all the reports on this area the rocks of this division have been recognized. They have been regarded, in the main, as representing the oldest or fundamental gneiss, and as constituting what has been frequently styled the lowest Laurentian.

Mr. A. Murray, 1853.

In the report of Murray, 1853, on the country along the Petawawa river and to the south and west, the existence of this lowest granite gneiss was pointed out. Over great portions of this area there appears to be an almost entire absence of the limestone and gneiss of the upper division, which are the predominant rocks of the Grenville and Hastings series. Along the north side of the Ottawa river, these newer rocks come in opposite the lower end of Allumette island, the limestones first showing about two miles west of the mouth of Black River and extending for some miles along the course of that stream northward. Along the north side of Allumette Island from the village of Chapeau, and on the roads along both sides of the Ottawa, in the vicinity, the reddish granite-gneiss is the prevailing rock.

The Bonnechère. Madawaska districts.

This old granite-gneiss is also well exposed along the upper part of the Bonnechère above Golden Lake, further to the south; and continuing in its course it occupies a large area in the west and northwest portion of the map-sheet under discussion. In this direction it is well exposed in the townships of Lyndoch, Abinger, Denbigh, Griffith and in portions of Metawatchan and Brougham, in all of which the rock is largely grayish or reddish-gray granite-gneiss.

Relations of the crystalline limestones.

In certain portions the foliation is well defined, but in other places it becomes indistinct; and the rock, as a whole, presents very different physical features from those that are found in the banded gneiss of the Grenville and Hastings series. Throughout the areas just designated the limestones of the upper series are, for the most part, lacking, and where they do occur their extent is very small as compared with the great masses which are found elsewhere. In places the limestone appears to rest upon the old granite-gneiss, but at others it is associated with a series of schists, amphibolites and gneisses, which are sometimes very garnetiferous, and which in turn rest upon the underlying granite-gneiss.

Irregularity of distribution

While the strike of the underlying, as well as of the newer rocks, follows a general north-east course, this direction is frequently and sometimes abruptly changed, so that the strike of much of the rocks of the newer series shows a tendency to follow the outlines of the underlying granite-gneiss. Instances of this are well seen in the township of Denbigh, as also at other points, where the lower series seem to have invaded the upper or overlying schists and limestone and diverted their strike for a considerable distance.

Granite-gneiss.

In the list of townships where the reddish granite-gneiss, which we now regard as constituting the lowest member of the crystalline series, is especially well represented, may be mentioned Grimsthorpe, Anglesea, Effingham and Ashby. In the second of these, which is almost entirely unopened to settlement, a large sheet of water, known as Loon lake, which intersects the central portion of the township, is reached by a road leading in from the Addington road. This latter road extends from the township of Kaladar to the Madawaska river, crossing the western portion of the township of Barrie, and furnishing, for the greater part of the distance, a very good cross section of the rocks of this area.

Loon lake.

Around Loon lake the reddish granite-gneiss is well exposed for the greater part of its outline. It forms large ledges along the north and west shores, and thence apparently occupies the northern and western parts of the township entirely. In much of this rock but slight traces of foliation are visible. The south-east angle of the lake, to near the outlet of the Skutematta river, is apparently largely occupied by similar rocks, but at this point the rock changes to a black hornblende gneissic schist or amphibolite which occupies all the south-eastern portion of the lake and extends across the country to the road through Barrie and on for some miles to the east. These black and green rocks are cut by dyke-like masses of red syenite or granite, there being often a small quantity of quartz in its composition, and these have broken up the hornblende rock with which they are now associated. Some of these dark rocks show but slight traces of foliation. They hold irregular bunches of quartz, while in the portions that are schistose quartz strings occur along the layers.

Black hornblende rocks.

The Addington road.

The granitic rocks also occupy the whole of the large point which separates the two arms of Loon lake and also the large island in the south-east bay. Thence they extend along the road from the lake to the Addington road and are exposed for some miles northward continuing as far as Eagle hill in the township of Denbigh. On the road going south towards Kaladar, the black hornblende rocks which were noted on Loon lake are overlain about lot 22, Addington road range, Barrie, by green chloritic schists, and thence on to Cloyne post-office, which is on lot 15, the green rocks prevail. In places these are distinctly dioritic in character, without foliation, but in other places they assume a schistose structure and present the aspect of true schists of the Huronian series as seen elsewhere. These green, sometimes slaty, schists, with occasional brownish bands of dolomite, thence extend southward into Kaladar township almost to North Brook post-office. Before reaching this place a band of slaty conglomerate occurs, the rock having a green slaty paste with quartz pebbles. From this post-office south to the road leading west to the Kaladar gold mine, the surface is largely covered by sand drift, but occasional ledges of grayish granite appear. On the path from this west road to the gold mine schists and slates come in, with bands of schistose conglomerate containing pebbles of quartz, which are drawn out along the lines of schistosity. The gold mine at this place occurs in this series of slates and schists, in which are rusty black bands with irregular bunches and strings of quartz. In these the gold is sometimes visible to the naked eye. The strike of these rocks is N. 25° E. with an east south-east dip of 70° to 80°. The principal mineral, in these schists is iron pyrites, with which the gold is generally associated. Bands of dolomite, brown-weathering and rusty, sometimes occur with the slaty beds which in places become true mica schists. This series of rocks, with their contained conglomerate bands, is continuous for many miles to the east, appearing at intervals in Clarendon and Palmerston townships, where their associations will be again referred to.

Kaladar gold mine.

Snow road.

The townships of Grimsthorpe, Effingham and Ashby are to a large extent unsettled, the surface being generally rough, and presumably almost entirely occupied by the granitic rocks which offer but slight inducement for the pursuit of agriculture. In the former no roads exist in the area on this map. In Effingham, the Addington road which skirts the west shore of the great Mazinaw lake for some miles, crosses, for a short distance, into the eastern margin of the township, while in Ashby the only highway is the "Snow road" which leaves the Addington road at the foot of Eagle Hill, and crosses a very rough and hilly country to Weslemcoon lake, which lies on the southern edge of the township. The road here crosses the creek connecting this lake with Otter lake, and thence, traversing the hills along the north side of Weslemcoon, crosses the Mississippi branch of the York river into the township of Mayo. This road is naturally very rough and but little travelled. There are only two settlers in the whole distance west from Ferguson Corner and the country all along is hilly with great masses of reddish-gray and grayish granite-gneiss which is usually moderately fine-grained. The rock is generally foliated but sometimes this feature becomes indistinct.

Weslemcoon lakes.

Weslemcoon, Otter and Thirty Island lakes are all important sheets of water in the southern portion of Ashby. The former is very irregular in outline, with long points and numerous islands. It extends into the northern portion of Effingham and at the south end a creek enters from Little Weslemcoon lake, the latter extending nearly to the centre of the last named township. From the south east end of the last lake a portage track extends across to the head of the Mazinaw lake, a distance of about four and a half miles.

Otter and Thirty Island lakes.

The whole of the township of Effingham, as far as yet examined, appears to be occupied by the reddish and grayish Laurentian granite-gneiss; and a similar rock constitutes the entire shore of the four lakes just mentioned. This rock is composed principally of reddish or grayish feldspar, black mica and some quartz. The strike along the Snow road is about N. 60° E. with a dip to the north-west, but at the end of the long west bay on the angle of Effingham, this changes to S. 25° E. $<$ 25° to 30°. At the creek between the two Weslemcoon lakes the rock has a grayer tint. The presence of dykes of coarse red pegmatite, sometimes of large size, is often noted. The same character of gneiss extends around the shores of Otter lake, and also occurs at Thirty Island lake. The surface soil of this township has, over many miles, been burned off and the bare ridges of the gneiss, often weathering a dirty white, are exposed in all directions, in places supporting a small green growth from which rise numerous dry trunks of the pine trees, which at one time apparently covered this area.

The township of Addington, like those just described, is also largely unopened for settlement. The Addington road traverses the western part near the line of Effingham, keeping near the shore of Mazinaw lake to its head, whence it follows along the valley of the Mississippi creek to Fergusons Corner at the foot of Eagle Hill in Denbigh. The north eastern portion is traversed by several roads, the chief one being the Snow road which, continuing from Eagle Hill, crosses the southern part of Denbigh into Abinger, whence it crosses Miller, Clarendon and

Palmerston townships to the line of the Kingston and Pembroke railway, near the point where it crosses the Mississippi river. This road affords a very good line of section across the south-west portion of the map-sheet.

Mazinaw lake.

In the western part of Abinger also, and extending half-way across the adjacent township of Barrie, lies the Mazinaw lake, one of the most beautiful sheets of water in the province, and noted for its magnificent cliff which rises abruptly from the eastern shore to a height of 360 feet above the water at its base. Fine exposures of the reddish and gray lower gneiss are seen along the shores, the strike of the rock being generally N. 60° E. with a dip to the southeast of 45° to 60° Along the face of the cliff, which is in the northern part of Barrie, there are bands which contain pyrites, and these by weathering have stained the face of the cliff with different shades of brown in irregular patches. These stains have by the Indians been regarded as representing old Indian paintings*. About one mile and a half from the foot of the lake a stream enters from the east which drains several lakes of good size, the principal of which are called the Kishkebus and the Shahbomekah or sometimes the Buck lakes. The reddish granite-gneiss continues southward along the shore of Lake Mazinaw from the upper end to the mouth of this creek, and extends eastward for some miles; but south of the creek the black hornblende rocks noted on Loon lake come into view and continue thence to the foot of the lake where a road falls in from the Addington road to an old lumber depot. Reddish granites here intersect the black hornblende rock as in the area further west.

Green chloritic rocks.

The north-east portion of Abinger contains a large development of green chloritic rocks mixed with epidote in places, which, near the village of Vennachar, show a well banded structure with a strike of N. 70°E. and a dip to the north. The intrusive red granite is also here seen. The green rocks extend south from Vennachar through the Beebe settlement where they are associated with hornblende and mica-gneiss; and as this road approaches the Snow road, about two miles east of the village, the strike changes to S. 60° E. with a dip to the north-east. The limit of these black and green rocks, or their contact with the granite-gneiss, is in the unopened area east of Mazinaw lake and could not be definitely ascertained.

To the eastward, this belt continues through Miller and North and South Canonto townships to the Madawaska river, south-west of Calabogie lake; and at the High Fall, is well exposed. Here it underlies the black hornblende gneiss, and limestone of the section, given by Murray in the Geol. of Can. 1863, pp 28-29.

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* Hennee the name of the lake, which is a corrupted contraction of the Indian word for picture.

Lakes in Barrie.

Furthur south, in the township of Barrie, somewhat different features are presented. This township is intersected by numerous lakes, generally long and narrow, among which the principal are Long lake, which is an expansion of the Mississippi river, and Marble lake, intermediate between this and Mazinaw lake; while to the north of Long lake is the Mississagagon and in the eastern portion of the township are Sand lake, McClintock and Shawenegus lakes. South of Long lake is another long and narrow body of water, known as Gull lake, which lies along the southern border of Barrie and Clarendon townships, and which, flowing east by Gull creek, discharges into the Cross lakes and thence into the Mississippi river about three miles west of the Kingston and Pembroke railway.

Gull lake.

Along the valley of Long and Mississagagon lakes the upper series of limestones and schists is well developed; but along Gull lake, for the greater part of its length a large development of the reddish granite-gneiss again appears, underlying the limestones. The northern limit of this gneiss area is a short distance south of Long lake, and the contact between the two series is to be seen on the Frontenac road between the Mississippi river and Gull creek, about one mile and a half south of the former. Southward, the older rock can be followed for some miles along this road into the township of Olden, and the belt has a breadth of nearly ten miles in this direction. Westward it extends into the townships of Kennebec and Kaladar beyond the limits of this map-sheet, while eastward it maintains a north-east direction, and though in places largely concealed by the green schist and diorite, reaches the overlying Palæozoic rocks in the township of Pakenham, on the south side of the great Ottawa basin.

The granite-gneiss of the area is usually moderately coarse-grained with occasional bands of blackish tint, and from its position evidently underlies the series of limestones and schists of the Hastings division. The rock is particularly well developed around the shores of the Cross lakes below Gull lake, and here forms a broad development to the south and east, reaching the Kingston and Pembroke railway and extending into North and South Sherbrooke townships.

Further south again, in the township of South Sherbrooke, and Bathurst, another approximately parallel area of this granite-gneiss comes to view, and extends with several interruptions eastward through the southern parts of Lanark and Ramsay, reaching the Palæozoic basin between Carleton Place and Almonte. The continuity of this band is interrupted at various points by the overlying masses of the Hastings limestones, schists and upper gneiss.

Four areas of granite-gneiss.

It will be seen from a glance at the structure of this area, as developed by the mapping, that four distinct and roughly parallel areas of the underlying granite-gneiss traverse the district; or, if we assume the area in the Madawaska portion to represent two distinct bands, separated by the narrow arm-like belts of the newer rock, five of the underlying bands of granite-gneiss may be recognized. All these several areas are separated by a series of newer sediments consisting largely of gneiss and limestone, the former often quartzose with certain bands of true quartzite, schists of various kinds, &c., the whole of which has been invaded at many points by masses of diorite, diabase and granite, sometimes in the form of pegmatite, which are evidently later in date than the calcareous and quartzose beds which they penetrate. From the movements which have affected all these rocks, subsequent to their formation, a general conformity in strike is now apparent; but that they are also unconformable in certain portions of the area, or that the schists and limestone series are of later date than the older gneiss division, is manifest from the relations here and there seen. Thus sometimes there is an apparently fairly regular sequence above the fundamental rocks into the upper members of the newer series, through gneisses, limestones and schists; at other times the limestone occurs in bands intimately associated with the granite-gneiss; while occasionally the schists rest upon this lower rock. From the fact also that the lower gneiss is apparently of igneous origin, while the members of the upper series are of sedimentary character, or at least large portions of these may be assigned to this category, an unconformity may be assumed.

Sequence of rocks.

THE NEWER LIMESTONE, SCHIST AND GNEISS SERIES, (HASTINGS).

Hastings series.

In the earlier reports of Vennor it would appear that, at the time of his investigation, the views as to the exact relation of the lower gneiss and the limestone series were by no means clear. Thus, in the Report for 1866-69, Vennor included in his lowest series not only the lowest gneiss, but also a great thickness, aggregating a supposed volume of nearly 11,000 feet, of gneiss, schist, diorite and crystalline limestone, the latter in places containing graphite.

Views of H. G. Vennor.

This view was however modified in the latest report on the district, 1876-77, in the manner named on page 277 of that volume, by restricting the lower member to the syenite or granite-gneiss without the limestones. Without entering upon a sketch of the history of the various changes which were made from year to year, as his studies in this field progressed, which would be productive of but little benefit, we may here simply give the details of the structure of the several members of the upper series, as observed in the various synclinals occurring between the areas of the lower gneiss just described.

In the comparison of the various rocks found in these basins, as they may be called, it will be observed that there are certain features common to all; while in some cases, owing to a development of strata and consequent increased thickness of the upper members of the series, there occur marked points of difference. It has not yet been found possible in this area to distinguish several distinct horizons in the calcareous portions of the series, as was originally done in the Grenville district, and later attempted by Vennor in the area under consideration.

Overlap of the Palaeozoic.

The volume of these newer rocks increases in a marked degree in the eastern half of the district; but here again much of the surface in the direction of the Ottawa, is occupied by the fossiliferous sediments of the Palaeozoic formations, which embrace all the divisions from the base of the Potsdam formation to the Trenton, so that the crystalline rocks of the upper division which have been frequently described under the name of the Hastings series, are almost entirely concealed for a distance of some miles before the Ottawa river is reached, near Arnprior. Similar rocks however reappear on the north side of that river and extend for many miles on the strike, in a northerly direction towards the height of land.

It would therefore appear, from a study of these rocks over a wide area, that a basin-shaped depression in the lowest crystallines occurs along the valley of the Ottawa, the western margin of which can be found about 100 miles west of the city of Ottawa, and it extends thence south to the vicinity of Brockville on the St. Lawrence river, To the north of the Ottawa river the greatest depth of this basin is found in the direction of the Gatineau and Lièvre rivers on the former of which the upper limestones have a very considerable development and extend northward for over 100 miles.

Limestone of Golden lake.

In the area comprised in the north-west portion of the map-sheet under discussion, between the Bonnechère and the Madawaska rivers the limestone and associated gneiss are but slightly developed. The limestone appears on the former river near the foot of Golden lake which apparently marks its western development in this direction. This is a short distance north of the limit of the sheet. On the

Opeongo road, which traverses the northern portion of the townships of Brudenell and Sebastopol, the calcareous bands are occasionally seen but their outcrops are of small extent, though there are exposures of the underlying quartzose and garnetiferous gneiss, which rest upon the lower series.

Giffith and Lyndoch.

Throughout much of the townships of Griffith and Lyndoch, the rocks are concealed by sand drift, and opportunities for the study of the underlying rocks are comparatively few; but along the Madawaska which traverses these townships they are seen in fairly good exposures. Here the limestone is found in small quantity and generally in narrow areas, which have a north-east strike, and in places are associated with bands of rusty and quartzose gneiss, similar to the rock asssociated with the limestone north of the Ottawa. The broadest band of the calcareous rocks seen on the upper portion of this stream is an extension northward of the area found in the central part of the township of Denbigh, where the limestone rests on the south upon a large mass of reddish gneiss, and the whole band with the hornblende rocks associated, has a breadth of several miles. It extends in an almost north direction along the valley of a creek which flows from several lakes to the south of Denbigh village into the Madawaska river, which it reaches at the north-east angle of the township. This band crosses the river, but is concealed on the north side by drift so that its development in this direction is unknown. A small irregular band of the limestone also occurs in the southern part of this township, but its course is to the west of north, as if it had been deflected by intrusive masses in its vicinity.

Denbigh.

Madawaska to Dacre.

Along the road leading from the Madawaska to Dacre, from the crossing in Griffith, gneiss and granite are the prevailing rocks for the first half of the distance. Then a band of limestone comes in and follows the course of the road into the southern part of the township of Gratton, where it widens somewhat, and continues through the southern part of Brougham township, into Admaston. Beyond this, to the Ottawa river, the limestone becomes associated with hornblende gneiss, schist, and some granites, and these last have exercised metamorphic action on the calcareous portion of the series. Some of these granites are associated with masses of anorthosite in the extension of this area, as in the townships of Ross and Horton to the south of Portage du Fort, and on the eastern half of Calumet island, where the limestone is sometimes entirely cut off on the strike or deflected at sharp angles.

Crossing the line of section from this belt in a southeast direction, the areas of the limestone and associated newer rocks become gradually more in extensive proceeding eastward. The most important of these, as shown on the Madawaska River section, appears on the stream in the southeastern portion of the township of Matawatchan, and extends south-west across the north-west portion of Miller. This belt extends in a north-east course through the eastern part of the township of Brougham, crossing the Madawaska at the Mountain chute and rapids, where it has a breadth of over two miles, and continues into the south-west part of Admaston township.

Section on the Madawaska.

In order to obtain as good a section as possible of the rocks across the central portion of this area, a traverse was made along the Madawaska river from the Palmer rapid, which is a short distance west of the limit of the sheet, to Calabogie lake, about twenty miles west of its junction with the Ottawa at Arnprior. This section is fairly complete, but there are certain portions where the rocks are concealed by drift.

Beginning then at Palmer rapids, it can be said that while the Madawaska may be classed as among the rough streams, its downward navigation is comparatively easy. There are a number of rapids and falls but the portages are generally good and many of the rapids can be run with a large canoe.

The Palmer rapids.

The rocks at the Palmer are reddish and blackish-gray quartzose gneiss, having a general strike of N. 70° E. and a southerly dip. This is broken up by masses and dykes of a coarse red granite which holds bunches of quartz and in which the mica is black. This granite contains aggregates of black hornblende, and sometimes of pyroxene, the gneiss is in places garnetiferous. It rests upon the southern side of a granite-gneiss area which extends across from the area west of the Madawaska into Brudenell and Sebastopol townships. The portage past the Palmer is about half a mile long or by crossing a small island midway two short portages can be made.

Aumonds rapids.

From the foot of the Palmer, where the mineral corundum has been found, to Aumonds rapid which is a fourth of a mile east of the western line of Lyndoch, the banks are usually low and sandy. Hills of red gneiss rise on either side of the stream, from a fourth of a mile to one mile distant. Aumonds rapids are about a fourth of a mile in length. The rock is a hornblende granite-gneiss, in places very black, with vein-like strings of hornblende and with bands of grayish gneiss, the strike at this place being S. 70° E. with a southward dip, the change in the strike being probably due to granite intrusions in the vicinity. The part of the river above this, to the Palmer, shows only three small ledges of reddish gneiss. Good farming lands lie along the south side of the river at this place, and a rough settlers' road extends from the Palmer rapid, where it crosses the river, to the village of Denbigh, by way of Wingle post-office.

Aumonds bay.

Below Aumonds rapids, where there is a portage of about 500 yards, ledges of coarse red granite appear, but with this exception, no rocks are seen on the river to Aumonds bay, about two miles distant. Here thin bands of crystalline limestone cross the river, and the rock is mixed with lumps of rusty gneiss and associated with gray quartzose gneiss and quartzite. Pyroxene also occurs here. The strike is N. 70° E., but the strata are much disturbed.

Snake rapids.

Below this to the Snake rapids the rock exposures are few. The shores are generally low and sandy for some distance inland. The Snake rapids are about three miles in length and consist of eight pitches with strong water all along. Most of these can be run with canoes, but the last three are very rough and are surmounted by short portages, the longest of which is 150 yards. The rocks all along are a grayish granite with much hornblende, and in places foliation is well defined. Certain portions of the rock here resemble an anorthosite. These are sometimes foliated but generally the strike of the foliation is too obscure for determination.

Veins of a hornblende-granite rock, with many crystals of hornblende, cut this granite, and quartz strings are common. Thence to the foot of the Snake rapids, which is at the old crossing of the Addington road, now abandoned because of the bridge having been burned some years ago, the rocks are mostly grayish and hornblende granite with some gneissic beds at the lower end.

On the old Addington road which is now closed for about five miles south of the river, as a wagon road, the only rocks seen between the river and the junction of the road from Denbigh to Wingle on the way to the Palmer, are granite and gneiss. The foliation is not always distinct, and the rock is often black or dark-gray from the presence of hornblende or black mica. No limestone appears along this track, but at the point where it turns off from the road west to Wingle, a strong band of crystalline limestone comes in with a strike a few degrees west of north. It could not be traced in the rough country northward but it may possibly be the same as that noted at Aumonds bay on the Madawaska river.

Slate falls.

Below the burned bridge on the old Addington road, the rocks for the next two miles, to Slate falls, show mostly dark hornblende-gneiss with strings of quartz. Slate fall is on lot 12, range XII, Lyndoch. The rock at this place is generally fine-grained granite and gneiss, the strike of the latter at the foot of the falls being north and south, with a dip to the east < 60°. The black colour of the gneiss is chiefly due to the presence of black biotite mica. There is a portage of 300 paces on the south side past the fall into a small bay, on the east side of which, resting on the gneiss, is a band of crystalline limestone, bluish-gray and banded like that of Arnprior and Renfrew. This rock is often coarsely crystalline and has patches of hornblende in the mass. The dip of the limestone is S. 80° E. < 65°. This limestone extends along the river for a couple of hundred yards, below which the banks are low and sandy. Several small islands below the chute are also composed of the blue slaty limestone, associated with schist and gneiss on lot 10. Thence down past the chain of small islands, the current is strong and the shores show ledges of black hornblende and mica-gneiss with a dip to the east < 40° to 60° as far as the sharp bend on lot 7. Red granite also shows along this part of the river.

Griffith.

Limestone again comes in at a bluff near the bend on lot 5. It strikes N. 20° E. < 80° and shows at intervals along the shores to lot 2, forming the rapids past the three islands to the town line of Griffith. This is the northeast extension apparently of the limestone area already noted in the township of Denbigh, which here crosses the Madawaska into the township of Griffith, and is there probably concealed largely by sand drift. The band of limestone exposed at this place is about three fourths of a mile broad, and the rock is similar in all respects to the typical Hastings limestone of Lanark and other places to the south. Much of the associated gneiss is a dark gray and rusty rock similar to that seen about Sharbot lake. It is frequently cut by granite dykes.

Hyland chute.

Midway between the west line of Griffith and Hyland creek, a small band of limestone crosses the river associated with gneiss and some granite. From this down to Hyland chute the rock is mostly a black biotite gneiss, very rusty in places and decomposing readily. It dips S. 40° E. and the small falls at this place are upon it. The rock is generally black, composed of quartz, feldspar and black mica; and is in places very pyritiferous. It is cut by small veins of granite and quartz, the latter occurring in strings and irregular bunches. Masses of dark-gray granite intersect the gneiss, and have twisted the stratification in all directions.

The portage past Hyland chute is 250 paces long and at the lower end there is a band of gray crystalline limestone associated with the rusty dark gneiss, the strike of the series being N.E. with a southeast dip of 75°. These rocks have pyritous bands and decompose readily, resembling in this respect the rocks along the Kingston and Pembroke railway, north of Sharbot lake. From Hyland chute down to the Griffith bridge the shores are generally flat. Heavy masses of reddish granite show on the south side of the river near the bridge which is at Hyland chute, and from this point the road from Denbigh goes across to Dacre. Much of the granite about this place is reddish but there are also black bands which resemble a coarse hornblende diorite.

From this down to the first rapids, at Campbells mills, the rocks, where seen, are mostly a reddish granite-gneiss. Along the roads to the south of the river this rock is seen at a number of places, and it appears to constitute a somewhat broad belt which comes across from the township of Denbigh at Eagle Hill.

Campbells chute.

At the mill and chute, there is a portage of 430 paces over dark-green hornblende rocks with some limestone in thin bands. The hornblende rock has the aspect of a diorite in places and the limestones are much shattered. This fall is called Campbells chute.

Below this, the road on the south side keeps near the river for several miles to the ferry which leads across into the township of Brougham. At the Wolf rapids and chute, which are about two miles west of the ferry, the rock is a blackish hornblende gneiss like that of Sharbot lake, holding very pyritous and rusty bands, with a strike of N. 30° E. and a high dip to the south-east. The gneiss of this area is nearly all black and hornblendic, with grayish, and sometimes reddish, bands.

Wolf chute.

From Wolf chute to the ferry the rock is nearly all gneiss, but just west of the ferry, bands of limestone come in. This rock shows thence at intervals to the head of the island above the Colton chute, where the rusty gneiss again appears and forms a chain across the river with a strike N. 40° E. dip S. 50° E. $<65°$. This gneiss is black with irregular bands of gray granite cutting it.

Colton chute.

Colton chute is a rough pitch over rusty black hornblende-gneiss along with grayish bands. The ingredients are coarsely granular and the rock has a clastic aspect. The lower part of the Colton chute passes over coarsely crystalline limestone, with bunches of quartz, interstratified with grayish quartz layers ; dip S. E. $<75°$. At another chute a fourth of a mile below the main Colton, the rusty blackish-gray gneiss appears, with bands of very coarsely crystalline limestone and masses of granite. Along the river the granites are generally fine-grained and reddish-gray.

Thence down for several miles, the river bank on the south side shows limestone, having a strike along the course of the stream which, is here about N. 60° E., and on the upper half of this stretch, the gneiss forms the north side of the river. The north side, to the point where the river turns sharply to the south, is mostly hilly and composed of granite and gneiss, while the limestone which shows along the south side forms the northern margin of a broad belt already described as extending from Miller to Admaston, in the course of which, to the northeast, it skirts the road extending west from Mount St. Patrick corner to Black Donald post-office in Brougham and forms a continuous band for at least fifteen miles.

The band of limestone which here comes to the Madawaska river is continuously exposed along the stream for several miles. It appears along the shore at different points to the big island at the head of the Chain rapids, and in places is tremolitic and cut by granite. The dip at the island is S. 60° E. Occasional bands of gray gneiss come in with the limestone to the next rapid at the foot of the island which is called the Cedars, and thence, to the head of the Mountain chute, the rock is nearly all limestone.

Mountain chute.

The Mountain chute is a very rough part of the river. The portage past it is 1,450 paces long over limestone all the way, and there are numerous heavy pitches which are apparently caused by dykes of reddish granite which intersect this rock. The strike of the limestone varies from N. 50° to 60° E. and the dip is generally at a low angle to the south. Below the Norway rapid, which is a short distance from the Mountain, the limestone still continues, the rock having much quartz in strings and bunches, but is otherwise the same bluish striped gray rock of the Hastings series, which is so common in the calcareous portion of that division.

Norway chute to High falls.

Limestone continues along the river to the entrance to Mud lake, which is on the south side, about one mile below Norway chute. Here it is associated with thin bands of the rusty hornblende gneiss, and the bands of limestone and gneiss are in frequent alterations. A short distance below this the reddish gneiss and granite again appear on the south side of the river and continue almost without interruption to the High falls, which is just above the entrance of the river into Calabogie lake. Several bands of limestone however show in the vicinity; and below the falls, beds of the black hornblende-gneiss, in places schistose, come in and form the rocks around the western and southern side of this lake. This is the place where Murray made his section in 1857, which is given in "Geology of Canada, 1863," pages 29-30.

Mud lake.

On the shores of Mud lake, just mentioned, which extend for several miles south from the line of the river, the rocks are largely granitic. Two small bands of limestone show along the east side, but near the upper or south end, the granites assume more the aspect of the oldest type, and the country to the south, in the direction of the Trout lakes in Canonto, appears to be very rough and composed largely of granite. There are no roads traversing this area, which is entirely unsettled, so that there appears to be a broad belt of the granite-gneiss between the limestone of the Madawaska, just described, and the belt which extends northeast from Barrie through Miller and the northern part of Palmerston, and which may be styled the third parallel belt of the upper series.

Calabogie lake to Arnprior.

On the portion of the Madawaska between Calabogie lake and the Ottawa river at Arnprior bluish-gray the striped limestones are well exposed below the outlet of the lake. Around the lake itself the rocks are largely schistose and hornblendic, with bands of limestone. Near the village of Springtown a band of coarse red granite, which is evidently newer than the limestone, comes to the surface and forms a considerable area between the Madawaska and the Kingston and Pembroke railway. This granite cuts the limestone and mica schist, and in the vicinity the former is very tremolitic. East of Burnstown, which is about seven miles to the south of the town of Renfrew the limestones, are the predominating rocks till they become concealed by drift and clay near the town of Arnprior, or are covered by the limestones of the Calciferous and Black River formations.

To the south west of the Madawaska river near Arnprior these bluish striped limestones have a wide development. They are especially well exposed to the north and east of White lake which crosses over into the township of Darling, and the breadth of the limestone in this direction is not far from eight miles across the strike. To the west of the area in the townships of Darling, Bagot and Lavant its volume is largely reduced and the principal rocks are schists, both micaceous and hornblendic, along with minor bands of reddish-gray gneiss which are especially well seen along the line of the Kingston and Pembroke railway north of Lavant station and thence to the town of Renfrew.

Schist and limestone.

This band of schist and limestone with grayish and black gneiss is one of the most important in the whole area. It can be traced continously from the western limit of the sheet in Anglesea and Barrie where it forms a well defined synclinal between the gneiss of Mazinaw lake on the north and of Gull lake on the south. The strike of the limestone and gneiss, west of the railway, is very uniform, with the exception of a few local twists and has a direction a little north of east or about N. 60° E. On the north of this basin the dip is to the south-east while on the south side of Long lake the dip becomes reversed to the north-west. The limestone is especially well seen along the shores and islands of Long lake and in that part of the Mississippi below this almost to Cross lake beyond the eastern line of Clarendon township. The limestone in places is blue and slaty, resembling in aspect some of the limestones of the Cambro-Silurian of the southern part of Quebec near Lake Memphremagog : but this rock assumes a highly crystalline character as it approaches the masses of intrusive granite or diorite. In places also the limestone is filled with quartz in the form of irregular strings and bunches, which give the mass a very ragged aspect on weathered surfaces, and form a feature easily recognized at many points throughout the distribution of this portion of the formation.

Long lake Mississippi river.

Sharbot lake east.

Another important area of the newer rocks of the Hastings division is that which appears in the southern part of the map-sheet, in the townships of Olden and Oso, at Sharbot lake. This area is bounded on the north side by the old gneiss of the Gull Lake belt and on the south by the similar rock which comes in between Sharbot lake and Bobs lake. It extends northeast through the townships of North and South Sherbrooke, and occupies the southern portion of the township of Dalhousie and the northern part of Bathurst, as well as a large portion of Lanark, continuing on into Ramsay where it is concealed by the overlying Palæozoic formations, here represented by the Potsdam sandstone and the Calciferous dolomite. In Dalhousie and Lavant townships, the limestones of this area are separated from those of the belt just described, by a great development of greenish dioritic and diabase rocks, and also by large masses of reddish granite, in which there are often but slight traces of foliation. In Bathurst the southern limit of these limestones is marked by Lake Bennett, which is an expansion, about five miles long, of Fall brook, a branch of the Mississippi river. The road east from Elphin corner to McDonalds corner, and thence south-east to Fall brook post-office, traverses this limestone belt for about eight miles. The limestones are the usual crystalline striped or banded variety, often holding veins and bunches of quartz with occa-

Lake Bennett.

sional bands of black hornblende and schistose gneiss, and sometimes with masses of granite. In the eastern part of the township of Lanark the limestone has a breadth of fully six miles and is terminated on the north by the red granite-gneiss of the western part of Pakenham which divides the area from the limestone of the White Lake belt.

In this area the schists are not so well developed as in the Lavant region, which may therefore possibly represent a greater development of the upper members of the series. Sometimes the limestone bands are broad and continuous for a long distance, but at other times their continuity is broken, either by thinning out, or by the sudden termination of the bands by intrusive masses.

Barrie and Clarendon.

The newer aspect of these rocks is well seen in the townships of Barrie and Clarendon, which are traversed by the Mississippi river, from the foot of Mazinaw lake into Palmerston. This stream, while flowing for a good portion of the distance somewhat along the line of the strike, affords a fairly good line of section. Beginning at the crossing of the Kingston and Pembroke railway, near the Snow road station, the several varieties of rock outcrops there found, with their relations, may be here described.

Section on the Mississippi river.

The lower part from the railway bridge westward is in a reddish granite-gneiss, sometimes tinged with green, and with masses of red granite, apparently intrusive in character. The gneiss strikes generally N. 30°-50° E. and dips S. E. < 20°-50°. These rocks are well exposed at Millers chute, about one mile above the railway bridge, where also bands of chloritic, epidotic and hornblendic rocks are associated. In places these rocks are schistose. From this point upward to the Ragged chute, which is a very rough part of the river along which a portage road of 1,200 paces extends, the rocks are largely a reddish gneiss or granite. At the Ragged chute, a band of white or cream-coloured limestone comes in, holding small inclusions of rusty gneiss, the whole being cut by dykes of white pegmatite. The limestone dips S. 40° E. < 20° and resembles much of that seen in the limestones of the Grenville series. Above this to the next chute, about 600 yards, distant, the rocks are again the red foliated granite-gneiss, the strike of which is N. 60° E. with a dip to the south-east. This same rock extends up to Kings chute where there is a portage of 370 paces over roughly foliated red granite, composed largely of red feldspar, quartz and black mica, and this rock continues upward to the foot of Croche or Cross lake where the strike of the foliation is N. 60°-80° W. with a dip to N. 30° E. < 15°-20°. The trail past the chute at the foot of the lake is 100 paces in length.

Ragged chute.

At the bend of the lake shore a fourth of a mile above the dam, the strike of the foliation changes to N. 40° E. with a south-east dip, and the gneiss is cut by dykes of red pegmatite. In character this rock resembles much of that styled, in the former reports, the Ottawa gneiss.

Croche lakes.

Croche or Cross lake consists of two parts connected by a creek nearly half a mile in length. The more southerly receives the waters of Gull lake, already referred to, by a creek about four miles in length. The reddish foliated granite-gneiss extends along the entire shores of the two Croche lakes, as also along the shores of Gull lake. In the latter area the red gneiss contains bands of black hornblende mica-gneiss, which in places weathers rusty; but no trace of limestone or garnetiferous gneiss was noticed in this direction. The strike of the rocks on Gull lake, as also on the upper Croche lake, is about N. 70° E. the dip being S. 20° E. < 40°. Dykes of coarse red granite are frequent and the rocks as a whole present features very like those seen in the area to the west already described.

Granite-gneiss.

On the lower Croche lake the red gneiss extends all around the shores to the inlet of the Mississippi river, or head of the lake. The strike and the dips are similar to those just given, but they sometimes vary a few degrees. Just above the lake on the Mississippi, the granite-gneiss is succeeded by a greenish and fine grained schistose gneiss, which weathers rough and nodular. The dip is S. 55° E. < 50° and the rock contains irregular quartz veins. The rock sometimes becomes schistose and this schistose character is seen as far up as the wing-dam, from which point a rough road leads off north to the village of Ompah. The dip here is N. 20° W. < 80°, and masses of fine grained granite are associated with the schist. Just above the wing-dam, heavy beds of rusty dolomite appear, in places with much quartz in the form of strings and bunches, and this overlies the schist. This point apparently marks the southern limit of the dolomite and schist series of the Clarendon belt.

Dolomite.

From this place to the bridge over the river on the road leading from Ompah to Ardoch, the principal rock outcrops are brownish or orange-coloured dolomite and dolomite schist. Above this to the second bridge at Ardoch, the hills on both sides of the river expansion known as Mud lake, also show frequent exposures of the ochreous-weathering dolomite. The rock in mass is sometimes pinkish-coloured but more generally has a yellowish tint. The islands in this lake are also largely composed of the same dolomite, but at the point at the lower portion of the bay, below Buckshot creek, and about one mile below Ardoch bridge, well bedded hornblende and mica schist come in, certain bands of which are studded with garnets. Veins and strings of quartz run along the bedding planes of this rock, and these are sometimes rusty and pyritous. The dip of the schists is S.E. < 70°. They underlie the dolomites of Mud lake and continue to Ardoch, where the dip changes to S. 30° E. < 70°.

The old Frontenac road crosses the river at this point and continues north-west to the village of Plevna, about five miles distant. On this road the limestones are associated with bands of black hornblende schist or schistose diorite for several miles. Their distribution in this direction will be referred to later.

Ardoch and Plevna.

South of Ardoch bridge the dolomites extend for about one mile and a half till they meet the mass of the Gull lake granite.

Gold.

In the area between Ardoch and Plevna there are several gold mining locations. The gold occurs in connection with black hornblende rocks which traverse the limestones, along with bands of reddish gneiss. At certain points dykes of dark diorite also come in and veins of quartz occur, some of which are gold-bearing and have been opened.

West of Ardoch, the shores of the Mississippi show ledges of dolomite and dolomitic schist which continue into Long lake, another expansion of the stream. At the first chute, a mile above the Ardoch bridge, these dip N. 35° W.< 75°. The carry here is 130 paces long. Above this the river widens into a lake with several islands, on which the dolomite is the principal rock, and then continues to a second pitch or series of small chutes, past which there is a portage of 500 yards to the foot of Long lake.

Long lake.

The dolomites along this part of the river are, on fresh surfaces, hard and fine-grained. They weather brownish and have partings of calcite and bitter-spar. At the foot of Long lake, the dip is reversed to S. 20° E< 50° and the rock contains strings of black hornblende. The cream-coloured dolomites are associated with hard siliceous bands and underlaid on the north side by a belt of reddish granite-gneiss, and the limestone at some points is much distorted.

Long lake is about twelve miles in length and the dolomites are exposed for the entire distance along the south shore, where they are sometimes changed to a highly crystalline saccharoidal cream-coloured rock. This is more particularly seen near the contact with a mass of granite-gneiss. The strike along this portion of the lake is N. 60° E. and the dip is N. 30° W < 40°-50°, but on the north shore the rock is often much less altered and frequently presents the aspect of a bluish slaty limestone which contains mica. This feature is especially well seen on the road which extends along the north side of the lake from Ardoch to Myers cove post-office, which is at the foot of Marble lake. The limestone is here associated with bands of black hornblendic, sometimes schistose rock, and these are cut by dykes of granite.

From the upper end of Long lake an old portage route leads across to the upper bay on Gull lake to the south. This route is now abandoned, but it was followed for some distance. The limestone of the lake shore was seen to rest against a belt of hornblende, sometimes gneissic rock with a dip to N.W. < 75° which was in turn underlaid by the reddish granite-gneiss of Gull lake.

At the narrows of Long lake which is near the upper end, the slaty, and somewhat schistose limestones, are much disturbed and sharply folded. The limestone continues to the west end of the lake which here widens out into a deep bay, and from this extends west in the direction of the Addington road towards Cloyne.

Whitefish lake silver mine.

The lake here turns sharply to the north and following up the river for half a mile, a rapid with a portage of 100 yards connects with Whitefish lake. At this rapid several pits have been sunk, in the attempt to mine silver-bearing galena near the contact of the limestone with granite dykes. The blue character of the limestone suddenly gives place near the contact, to a highly crystalline condition and the rock becomes a marble. But small trace of lead ore is seen in these rocks at this point, though the rock is somewhat cavernous. This is Myers Cave mine. The rocks strike generally N. 60° E. in a nearly vertical attitude. Similar associations of the limestones and slaty schists show around Whitefish lake to the foot of the chute at the outlet of Marble lake, on which there is a sawmill; and the road from Ardoch to Myers Cave post-office, here crosses. Here hard bluish-gray slaty and micaceous rocks cause a fall of about 20 feet, and the limestone in the vicinity is highly crystalline. The strike is N. 65° E. and the dip vertical, and just above the dam a great mass of hornblende diorite rock comes in on the west side which is apparently intrusive in the limestone. The Helena copper and gold mine is situated on the east side of the lake on lots 19 and 20, R. VI and lot 20, R. VII, Barrie.

The Helena mine.

Marble lake.

In Marble lake the south shore of the main bay is occupied by green slaty schist sometimes highly micaceous, which is similar to that seen on the road south from Cloyne to Kaladar. With this are associated dolomites and dolomitic schist, the dip of which is N. 35° W < 80°. Above this to the head of the lake, or to the foot of Mazinaw lake, there is considerable development of the crystalline dolomite or marble which shows on the western shore and in the river above, and from which the lake takes its name. The rocks of Mazinaw lake have already been described on a preceding page. The black hornblende bands come in between the marble of this lake and the reddish gneiss.

The synclinal structure of the Long lake area is thus well established by the dips on either side, and the metamorphic action of the diorites and granite is clearly seen at a number of places. The same features appear in connection with similar blue slaty limestones of this series, further east in the township of Lanark, which will be referred to later.

Lake Missasagagon.

To the north of Long lake, on the Mississippi, lies Missasagagon lake. It discharges into Buckshot creek, a tributary of the Mississippi, by Swamp creek, and is long and narrow. The west end of the lake is reached by a portage of half a mile from the foot of Marble lake and shows beds of limestone, with interstratified bands of black hornblende gneiss, the rocks being the eastern extension of those seen on Marble lake. The north side of Lake Missasagagon is occupied for the most part by the blue slaty limestone, much twisted in places and resembling the beds seen on Long lake to the south. The dip of these is generally north-west at a high angle. Near the east end of the lake a portage road leads across to another chain of lakes, among which are McClintock's and Sand lakes. The portage is 1,200 paces long and the limestones extends for 700 paces to a band of black hornblende rock similar to that seen on the north side of Gull lake. This has a breadth of about 100 yards and rests upon the reddish granite-gneiss which extends from Mazinaw lake and which, further east, crosses the Snow road about three miles north of Plevna village. The islands in this lake, as well as the south shore, are mostly composed of the blue slaty limestone with bands of black hornblende rock, and with diorite masses. Between this lake and Long lake on the road from Ardoch to Perry, on lot 13, range VIII, Barrie, a silver mine was some years ago opened which disclosed rich ore and was worked to some extent, but the property became involved in litigation and work has long since been abandoned. The rocks at the mine are limestone with mica and hornblende schist and the ore is argentiferous galena.

Silver mine in Barrie.

This road, from Ardoch west, along the north side of Long lake to Myers Cave runs for the greater part of the distance over the slaty limestone. With this are bands of black hornblende schist, the dip being generally N. 30° W. < 40°-60°. An occasional reverse dip to the south-east is seen in these rocks near the head of Long lake, but the strike of the series is very uniform.

Long lake to Harlowe.

From Myers Cave post office, at the foot of Marble lake, a road south passes by the end of Long lake and extends to the line road to Harlowe and to the head of Gull lake. On this road the limestones extend past the south-west bay of Long lake and are generally highly metamorphosed. They are met in this direction by granitic and amphibolite schistose rocks, the latter being sometimes greenish coloured, and often massive, with a marked dioritic aspect in many places. The surfaces often weather rough and nodular, giving the rock at times a coarsely conglomeratic appearance. Occasional bands of dolomite occur with the greenish schist portion. These continue south to the Harlowe road, which extends east from the corner on lots 26-27, between ranges II and III, Barrie. On the south side of this range line road, hills of black hornblende rock, sometimes schistose, appear, overlying the reddish granite gneiss ridges to the south, which thence continue along the course of Gull lake and out to the line of the Kingston and Pembroke railway.

Cloyne.

These rocks are similar to those seen on the Addington road, south of Cloyne post-office. In places they strongly resemble eruptive rock, being massive and sometimes porphyritic; at other places they present the appearance of true hornblende, chlorite or mica schist. On a road leading out from this corner to the Addington road which it reaches about a mile and a half south of Cloyne post-office, a broad belt of well banded limestone comes in, which is evidently the western extension of the Long lake band, but which is apparently terminated somewhat abruptly before reaching the Addington road by a mass of green diorite, with granite, which is there well developed, since the only traces of the limestone seen in that direction are certain narrow bands of dolomite.

Old Frontenac road.

Contact near Ardoch.

A section of the rocks seen along the old Frontenac road which extends from Mountain Grove station on the Canadian Pacific railway, across the country north to the Madawaska river, shows the structure of this basin in considerable detail. The southern portion is largely composed of granite and gneiss, and the contact with the rocks of the overlying series is about two miles south of the bridge across the Mississippi river at Ardoch. Here the lower or hornblendic portion of the series comes in and is shortly overlain by the ochreous dolomites. This is near the road which turns off east to Green lake, along which also the dolomites are well exposed. The dip of the reddish granite-gneiss at the contact is N. 30° W. Thence to near the river the dolomites dip regularly to the north-west. Near the Ardoch bridge, bands of hornblende rocks with some red gneiss, and granite dykes are interstratified. Just north of the bridge a band of the hornblende schist comes in, reaching nearly to the forks of the road which passes by Long lake. Then limestones, sometimes blue and slaty, at other times highly crystalline, extend for several hundred yards. About three-fourths of a mile north of the forks of the roads the dip is reversed to S. 30° E. < 80° and the hornblende rocks become more widely developed; but the limestone again appears in a broad belt which extends along the Plevna road to a point half a mile north of Swamp creek, the south-east dip being maintained at angles of 50° – 60°. Here it is underlain by a band of hornblende granite-gneiss, with a breadth of about two miles, which extends to within half a mile of Plevna post-office. This is overlain by a broad area of crystalline limestone which in places is blue and slaty, and which is exposed along the roads to Plevna and north of that village as far as Tooley's stopping place on the Snow road. It is also well exposed along a road which extends west of Plevna to the town line of Barrie. This band shows a well defined synclinal structure, the dips near Plevna being north-west < 80°, while near the north limit of the area this is reversed to south-east. Associated with the limestone are bands of hornblende and mica schist, and the basin of newer rocks is terminated northward by the underlying mass of reddish granite-gneiss of the Mazinaw belt. This granite area extends along the Snow road for a couple of miles, beyond which, in this direction, a second basin-shaped area of greenish hornblende schist and allied rocks continues to Douglas's house, where the portage between the Brulé and Buckshot lakes crosses the main road. This band is narrow, and the granitic gneiss again comes in and extends to the eastern line of the township of Abinger, the western limit of which is seen near the forks of the road at Mallory hill. This belt of the granite-gneiss shows an anticline and is, at this place, overlain by another broad belt of the schists which occupies the north-east portion of Abinger and extends to the corner at Vennacher, already alluded to, and which is apparently the western extension of the belt of schist and limestone seen on the Madawaska river which it crosses at Mountain chute. This area of schists apparently terminates in the rough country between this road and the head of Mazinaw lake.

Snow road west of Plevna.

Vennacher.

Snow road east of Plevna.

Eastward of Plevna, the Snow road continues through the eastern half of the township of Clarendon and across Palmerston, till it meets the Kingston and Pembroke railway north of the Mississippi river bridge. This road, for more than twelve miles, or to a point several miles east of the village of Ompah, traverses almost continuously a broad band of crystalline limestone. In places this is highly altered, the rock containing much quartz in strings and bunches, which gives

Ompah.

a very ragged surface when weathered. The strike is uniformly N. 60° E., and the dip is for the most part to the north-west, though this changes about one mile west of Ompah to south east < 50°. Near this village the limestone is associated with bands of greenish rusty schist, some of which, across the strike, have a breadth of 300 to 400 yards.

Slaty conglomerates

A road turns off south from the Snow road about one mile west of Ompah and crosses the Mississippi river which is nearly four miles distant to the south. Along this road the rocks are mostly limestone with occasional bands of schist, and about one mile north of the river, bands of slaty conglomerate, with quartz pebbles, appear, which are similar to the conglomerates noted in Kaladar, south of Cloyne. They have also been observed at several intermediate points and thus appear to be fairly persistent. The pebbles in this conglomerate are drawn out in the direction of the planes of the bedding. They were observed also along another road which extends south of Ompah corner towards Mississippi river.

Road from Ardoch to Ompah.

This broad band of limestone is also well displayed along a road which traverses the area north of Mud lake (Mississippi river) which extends from the Ardoch-Plevna road to the road south from Ompah near the second bridge. Here dolomites and striped limestone are almost constantly exposed for nearly four miles diagonally across the strike, and the rocks show the presence of several folds. Near the eastern end of this road the limestone bands are interstratified with schists and hornblendic rocks. These rocks are the western prolongation of a broad area of schists, limestones and hornblende rocks, which are well developed in the townships of Lavant, Darling and Bagot, and which thence reach the Ottawa near the town of Arnprior, where the limestones have a still wider development and extend over portions of MacNab and Pakenham townships.

Palmerston township.

The north east corner of the township of Palmerston is traversed by several roads. Of these, one extends from Lavant station on the Kingston and Pembroke railway to the junction of the Snow road which comes up from the Mississippi river, at a point about three and a half miles west of the station. On both these roads the limestones of this series are well exposed, but the bands are somewhat narrower and the schists and upper gneisses are more extensively developed. They are frequently cut by dykes of granite and by diorites.

On the road west from Lavant station, the strike of the limestones and schists varies from N. 30° to 60° E. and the dip is to the south-east < 25° to 50°, but on the road from Snow road station to this road several flat-lying folds are seen in brownish and rusty schistose gneiss with dips of five to ten degrees.

Ompah to Folger station.

On several roads north of the Snow road the rocks are less calcareous and the schists and red granites more exposed. One of these roads extends from a short distance east of Ompah, by way of Trout lake, to Folger station. Near the crossing of the Clyde river, west of the railway, chloritic and epidotic rocks are well displayed. The road east of Ompah past Trout lake, shows varying strata of schist and limestone, the dip of which is uniformly to the south-east, and the same prevailing dip is seen on a couple of cross roads which connect this with the Snow road.

Trout lake.

The north side of Trout lake, which is traversed by the township line of Palmerston and South Canonto, apparently marks the northern limit of this limestone area. North of this, to the Madawaska river, the rocks more closely resemble the underlying granite-gneiss series, with which are occasional bands of hornblende rock with some thin limestones, but the red granite apparently occupies the greater portion of the township of Canonto, the surface being rough and hilly and unopened by roads, to the limestone belt indicated on the Madawaska section at Mud lake.

Miller township.

In the township of Miller, several large lakes are found. Among these may be mentioned Buckshot, Brulé, Fortune, Skeads and the Schooner lakes. Lake Buckshot discharges into the Mississippi near the village of Ardoch, but the others flow into the Madawaska by way of Skeads and Mackay creeks. This last enters the Madawaska river about a fourth of a mile below the Colton chute, and a very fair section is presented across the township.

Schooner lake.

Ascending from the Madawaska river by Mackays creek, the limestones, which are in places highly tremolitic, extend for about half a mile. Then a band of hornblende gneiss comes in, of about the same breadth, above which mixed limestone and gneiss extend to the outlet of Schooner lake, the calcareous rocks largely predominating. Heavy dykes of whitish pegmatite cut the rocks of the series, and at the entrance to the lake the dip of the limestone is N. 40° W. The strike of the underlying reddish granite-gneiss, which is sometimes well foliated, but at other places massive, is about N. 20° W. < 40°. The limestone at this locality is also tremolitic and in parts filled with bunches and strings of quartz with occasional irregular bands of rusty gneiss, resembling in this respect much of the Grenville limestone. The limestone at the outlet of Schooner lake marks the south side of the belt which crosses the Madawaska river at the Mountain chute.

Skeads and Mackays lake.

Around Schooner lake the rocks are mostly reddish gneiss, which is cut by dykes of granite, often fine-grained. At the narrows connecting with the next or Skeads lake a band of very coarsely crystalline limestone appears with bunches of white quartz, and this is cut by a heavy dyke of red granite, 50 feet wide, which is evidently more recent than the limestone. The latter rock occupies the greater part of the north shore of the second lake, and at the upper end a creek and short portage leads into Mackays lake. The south shore of Skeads or second lake is occupied largely by the red granite-gneiss, and the same rock occupies the greater part of the shores around Mackays lake. The strike of all these rocks is about N. 70° E. and the dip N. 20° W. < 20°-40°. Much of the granite, however, shows but small traces of foliation.

Fortune lake.

From the outlet of Schooner lake, a route by way of Skeads creek leads to Fortune lake, and the limestone is exposed at intervals all the way. On Fortune lake the limestone occupies the north side and the greater part of the west shore. It is cut by many dykes of the red granite. On the east side of the lake exposures are fewer, but hills of the granite rise in the direction of Mackays lake and masses of the black hornblende rock come in. This rock is well seen on the southern end of Fortune lake, and extends across to the northern end of Brulé lake, but a band of limestone comes in along the connecting creek and extends along the north end of the latter, reaching the old Frontenac road which crosses from the Snow road into Metawatchan township, and thence to the Madawaska river. On this road the limestones and schist are underlain by the reddish granite and black hornblende gneiss, which form most of the shores of Brulé lake. The dip of these rocks where seen is N. 20° W. < 20°-50°.

Brulé lake.

Section on Kingston and Pembroke railway.

Further east along the line of the Kingston and Pembroke railway a good section is afforded, both of the upper and of portions of the lower gneiss. This section extends from Sharbot lake, which is on the southern margin of the map-sheet, to Renfrew which is just at the northern margin. The railway, for a considerable part of this distance, follows along the strike, or cuts this diagonally; but shows the relations of the two series at a number of places. The rocks between Clarendon station and Calabogie are of economic importance since in this part of the area some of the largest and most valuable of the iron ore deposits of this district are situated.

Sharbot lake.

Sharbot lake, which lies just south of the map-sheet, is divided into two parts, the connection being by a narrow creek, across which both the Canadian Pacific railway bridge and the highway road crosses. The rocks in both lakes comprise areas of crystalline limestone associated with bands of black hornblende gneiss and schist along with red granites and gneiss. The latter feature is more especially seen in the eastern portion of the east lake, while the black hornblende schistose gneiss is better developed near the narrows between the two. The narrow point between the lakes is composed principally of crystalline limestone, with a dip S. 50° E. < 35°-40°. This is cut by dykes of granitic rock which have disturbed the original bedding of the limestone. The rock is generally coarsely crystalline, but often banded or striped, like that of Renfrew and Arnprior. At the east end of the railway bridge there is a cutting in reddish-gray micaceous gneiss, well foliated, and with partings of thin bedded shaly gneiss, the dip of which conforms with the limestone near the station. South of this along the railway (K. and P.) there is a succession of hornblende schists and gneiss, cut by dykes of red granite for several miles, having a uniform south-east dip < 40°-70° to near George lake where they are overlain by crystalline limestones which apparently conform in dip with the underlying schistose gneiss.

Around the shores of west Sharbot lake, the principal rock exposures are blackish hornblende schistose gneiss. This is often much decomposed and on weathered surfaces is generally very rusty. In places these rocks are cut by black coarse hornblende diorite; but a band of limestone extends in a curving outline through the centre of the lake and shows on the south side of the long point at the western extremity, as well as on several of the islands intermediate between the foot of the lake and this point. The strike at the west end of the lake is east and west with a south dip < 45°, so that the limestone is apparently an interstratified portion of the hornblende schists of this locality.

Along the line of the Kingston and Pembroke railway, north of this place, the strike changes to a more northerly direction, and in the limestone and rusty rocks, at a distance of a mile north of the station, is nearly north and south, dipping east < 20°. Near the first road crossing on the railway the dip again swings round to S. 40° E. < 35°; but, between this and Oso station, the limestone and schist are apparently cut by masses of red granite, and the strike varies from N. E. to N.W., the dip being however easterly in both cases.

Oso to Clarendon.

From Oso station to Clarendon station, ledges of crystalline limestone are frequent and cuttings in this rock are seen at intervals for the greater part of the distance. The limestones frequently present the banded aspect so common to the limestones of the Hastings series, and dykes of reddish granite are common. Along this part of the section the dips are very uniformly to the south-east and vary from S. 30°–55° E. < 40°–50°, but at one point about midway, near a mass of blackish diorite, the dip swings round to S. 10° W. < 45°, though the strike speedily changes again to the normal direction of N. 60° E. Near Clarendon station, and for nearly a mile and a half south of that point, masses of hornblende gneiss and granite occur with several minor bands of limestone.

The seemingly broad band of limestone noted on this portion of the section north of Oso station does not appear to extend far to the east. It is terminated in this direction apparently by masses of red granite and by hornblende or amphibolite rocks which form large areas between the railway and the western line of the townships of North and South Sherbrooke, but the limestone band of Sharbot lake extends continuously into South Sherbrooke, and further east it occupies a large portion of the southern half of Dalhousie, nearly the whole of Lanark, and the northern part of Ramsay, till it is concealed by the Palæozoic rocks of the Ottawa basin east of the Mississippi river.

Clarendon to Snow road.

Between Clarendon and Snow road station, which is a short distance north of the crossing of the Mississippi river, the limestone outcrops are few. The rocks are mostly red granite, sometimes gneissic, with masses of black or dark green diorite, and near Mississippi station, bands of hornblende schist. At this last place a band of limestone crosses the railway with a dip of S. 55° E. < 30°, which contains much quartz, and this continues on the strike across the river into the northern part of the township of North Sherbrooke, where it is cut off by masses of intrusive granite and diorite. The limestones at this place are much altered. They are invaded in all directions by the intrusive rocks which sometimes cut them off on their strike, and sometimes contain masses of the limestone as if caught up in the diorite mass. The limestones are also filled with bunches and masses of quartz. The Robertsville iron mine occurs a short distance east of the railway at Robertsville station.

Iron mines.

Between Mississippi station and the Mississippi river the rocks are mostly red granites, sometimes massive, but occasionally well foliated; but north of the river, in the vicinity of Snow road station, beds of hornblende and mica schist come in. These are cut by dykes of red granite and by masses of the same rock. The strike of the foliation in the granite near the bridge over the Mississippi river is N. 10° E. and the dip is S. 80° E. < 10°.

Snow road north to Lavant.

North of Snow road station toward Lavant, red granite with mica and hornblende schist, continues along the track for a little more than three miles, to a band of white limestone which overlies the schist. The dips of this series, while generally to the south-east, range from S. 20°-70° E. < 10°-40°, being sometimes suddenly deflected as if through the agency of some intrusive mass. From the point indicated where the limestone first appears on the line of railway, the rocks to Lavant consist for the most part of micaceous and hornblende schist with bands of limestone, the dips as already noted. Occasional masses of red granite show through the schists and limestone. In the northern part of this section the iron mines, called the Wilbur and the Caldwell, are located. The rocks at these mines are largely green chlorite schist, with red granite and dolomitic limestone. The whole are much broken up, apparently by a mass of red granite which cuts the rocks at this place and forms a prominent ridge to the south-east, extending along the east side of the road which leads from the Wilbur mine to the road running east from Lavant station to Poland.

Iron mines.

Lavant to Flower station.

From Lavant station to Flower station the rocks vary somewhat from those just described. There is a greater predominance of mica and garnetiferous schists, and the granite areas are of smaller extent. At the former station the banded and white limestone dips N. 70° E. < 15° and extends for nearly a fourth of a mile to a mass of red granite. This continues for nearly a mile and a half or to within half a mile of Folger station, where it is met by rusty hornblende schist which dips S. 40° E. < 85°–90°. North of this station, granitic, hornblende and epidote rocks extend for three-fourths of a mile, with a similar dip < 70°. Here a band of mica schist, bright and silvery on cleavage, comes to the railway. This rock is sometimes purple-tinted and it extends for three-fourths of a mile, with a dip of S. 20°–30° E. < 60° to a band of limestone with the same dip. From this to Clyde forks the schists are again strongly developed with bands of pinkish and gray dolomite, the dip remaining constant to the south-east, with variations of 20° to 40° degrees. The schists strike N. to N. 30° E. and extend eastward, crossing the road south from Calabogie lake to Darling township. Near Clyde Forks they are cut by masses of red granite. Along the railway thence northward the dolomites and schists continue for about a mile beyond Flower station. On the road south-east from the station toward Joes lake the schists are well exposed till they meet the reddish granite gneiss south of the Clyde river, but from the point indicated north of Flower station to the head of Calabogie lake the rocks are largely hornblendic with occasional thin bands of crystalline limestone or dolomite, and the strike is nearly north and south

Clyde forks.

Calabogie lake.

with a dip to the east. Approaching the lake, the dip swings round to N. 70° E. < 40° and thin bands of the limestone come in near the shore. About half a mile south of Rathbun's switch the dip again changes to S. 65°. E. and the rocks are broken across by coarse dark diorites. East of this to the crossing of the south bay of Calabogie lake the rocks are drift covered, but an outlier of Black River limestone here comes in with a breadth of nearly a mile, and is well exposed on a road to the south about a mile distant.

Between this bay and Calabogie station the south side of the lake is occupied by a band of crystalline limestone, through which a deep cutting has been made for the railway. This rock is dolomitic and has interbedded layers of hornblende and mica schist in places, the whole being cut by dykes of red granite. The dip of these rocks is S. 30° E. < 25°. The limestones are sometimes tremolitic, and they are well exposed around the east end of the lake and through Calabogie village. Near the station the strata are nearly flat, while along the river, below the railway bridge, the hornblende rocks are well exposed with a dip of S. 30° E. < 30°. To the south of this place, large deposits of magnetic iron ore occur which have been worked at intervals for some years. Some of this ore is apparently of excellent quality and apparently quite free from sulphur, but certain portions, judging from the ore in the dumps contain small quantities of pyrites and may be classed as sulphurous.

Calabogie to Renfrew.

From Calabogie to Renfrew town the railway presents many outcrops of rock and cuttings are numerous. The schists are often highly micaceous and are associated with bands of dolomite which is frequently beautifully tremolitic, fine specimens being obtainable at several places. A considerable area of blackish gray diorite rock, with granite and syenite occurs between Norway lake and Ashdod station, and extends for nearly a mile south of the former place, where it is in contact with the schists and limestones which are thence exposed almost continuously to Calabogie. Several low anticlinals are seen in this part of the section. East of Ashdod the same granitic rocks continue for about three-fourths of a mile to similar schists and dolomites. The latter frequently present the striped or banded aspect, seen so often in the limestones of the Hastings series, but are frequently cut by masses of the red granite, when they become highly crystalline. These schists and tremolitic dolomites are exposed almost continuously to within a few hundred yards of Opeongo station, the dip being generally S. 60°–70° E. < 20°–40°, but occasionally there is a reverse dip to the north-west. Masses of pegmatite and red granite are seen at intervals. East of this station to Renfrew Junction, which is one mile west of the town, the rocks are more hornblendic and sometimes gneissic, but have associated bands of mica schist. At the crossing of the creek in the west part of Renfrew near the cheese factory, a band of coarsely crystalline pinkish limestone shows in the bed of the brook, with a dip of N. 10° E. < 50°, and in the town itself are heavy ledges of bluish-white striped limestone like that of Arnprior, which are extensively quarried for building purposes, and for lime burning, in which the dip is N. 20° E. < 15°. The black hornblende schist shows along the roads just south of the town, dipping beneath the limestone.

Granite areas.

In the townships of Lavant, Darling and part of Bagot the largest development of the schists just described is seen. In the western portion of Lavant these are interrupted by a mass of reddish granite-gneiss which is apparently an extension north-eastward of the large mass seen in Palmerston and North Sherbrooke, and which reappears further to the north-east along the north side of White lake in the southern part of Bagot and MacNab.

Area east of Kingston and Pembroke railway.

East of the Kingston and Pembroke railway the townships are for the most part well opened up by roads, and the examination of the country is correspondingly facilitated and comparatively easy. The southern part of the map-sheet is crossed by the line of the Canadian Pacific railway which traverses the area between Carleton Place and Sharbot lake, and along which rocks of Potsdam and Calciferous age are exposed, from the first named place to a point several miles west of the town of Perth. West of this, however, the rock exposures along and near the line of the railway, are of reddish gneiss and granite. A band of crystalline limestone comes in about one and a half mile east of the west line of the township of Bathurst, and continues for several miles to the westward. It has however but a small development throughout most of its outcrop, and apparently disappears near the east line of the township of Oso. It may represent one of the small bands which has been noted as occurring on the east side of lower Sharbot lake.

Section south of Maberly.

A section along the road south of Maberly, to the south line of South Sherbrooke, shows, for some miles south of the Canadian Pacific railway, a succession of outcrops of generally reddish granite-gneiss with bands of hornblendic gneiss and granite. A short distance north of the bridge which crosses the Tay river midway between Christie lake and Bobs lake, the limestone band which is seen on the latter, as also on Fagans lake to the south, is met. This band has in places a breadth of a mile and extends eastward, apparently crossing Christie lake and continuing in a narrow outcrop into the township of Bathurst. The road south of the Tay eastward, towards Perth, after crossing the limestone area, passes over almost continuous exposures of reddish gneiss, with occasional masses of granite, till it meets the overlap of the Potsdam sandstone. The strike of this gneiss is N. 50°-60° E. and the dip generally north-west.

Bathurst.

Throughout the township of Bathurst the red gneiss and granite are the prevailing rocks. An occasional small area of crystalline limestone appears but the rock is essentially a granite-gneiss to the south shore of Bennett lake in the northern part of this township. At this latter place the extension of the limestone belt, noted at Sharbot lake station and along the roads east of that place, comes in and occupies apparently the whole of the area of the lake which has a length of about five miles, being long and narrow; this band continues, with a widening area, eastward into the township of Lanark. The calcareous rocks are well exposed at Fall brook where they are interstratified with grayish and often rusty gneiss forming apparently the southern limit of the main limestone area of Lanark and Dalhousie townships.

Fall brook.

The strike of the limestone and associated gneiss is very uniformly N. 60° E. varying from N. 80° to N. 50° E. for short distances. The prevailing dips over large areas are to the south east, but reverse dips to the north-west are noted at several points. In places the limestone is bluish and slaty, resembling that on Long lake of the Mississippi already described. This slaty feature is well seen a short distance west of Lanark village, but more frequently the rock is highly metamorphic and contains an abundance of quartz in strings and irregular bunches, which on weathered surfaces gives the mass a very rough appearance.

Dalhousie.

In the north portion of Bathurst and in the southern part of Dalhousie which adjoins it on the north, the belt of limestone has a breadth of several miles extending to the shores of Dalhousie lake. In the south-west corner of the last named township it is associated with hornblende rocks which are well exposed to the west of the road leading from Playfair to McDonald's corners. The north-west limit of this limestone area is seen near the south-west angle of Dalhousie lake, where it is in contact with the mass of red granite of South Sherbrooke, but along the road from McDonald's corner almost to Elphin, the calcareous beds are well exposed. They are well banded or striped and have a dip of S. 40° E. On the road from this corner to the foot of Dalhousie lake they are also well seen, and they occupy the lower end of the lake, on the north side, for about a mile above the outlet. From the foot of the lake along the straight road leading to Watsons corner the limestone is almost constantly exposed but the dip is here reversed to N. 20°–30° W. $< 30°$, showing the presence of an anticlinal in this direction. About midway between the foot of the lake and Watsons corner it is invaded by a mass of red granite, but this does not apparently affect the general run of the strata. These limestones present the striped aspect already referred to.

Dalhousie lake to Poland.

On the road north from the foot of Dalhousie lake towards Poland the calcareous strata extend for about a mile to a mass of red granite, which is thence exposed along this road to Patterson lake, and further on becomes associated with masses of black or sometimes greenish hornblende rocks which extend thence, with but slight interruption, to the northern limit of the township. On the road north from Watsons corner between ranges II. and III., the striped or banded limestone extends for about a mile also, when it is met by granite ridges, and becomes in places interstratified with beds of grayish and sometimes rusty gneiss. Along this road about three miles distant from the corner there is a deposit of pyrrhotite with diorite in the rusty gneiss which has been slightly opened up, and the mineral found to contain a small percentage of nickel. There are alternations of limestone and gneiss with granites for about three miles north of Watsons corner, when the calcareous portion of the series apparently disappears in this direction. The last outcrops of the limestones are noted about half a mile north of the church at the cross roads on lot 16. Thence north to the limit of the township the rocks are red granites with great masses of black hornblende diorites in which there is generally no trace of foliation. These hornblende rocks occupy a large portion of the northern half of the township of Dalhousie. In places a schistose structure is visible, but for the most part the rock is massive. They extend into the southern portion of the township of Lavant adjacent on the north, where they are also mixed up with masses of reddish granite, forming a rough country of but small agricultural value. Detached areas of dolomite of limited extent are occasionally seen which weather very brown and are ochreous, assuming sometimes the character of a dolomite schist, and the massive rocks of the district generally present the features of intrusive rocks in the schists and limestone.

Poland west to Lavant station.

Poland village is in the northern part of Dalhousie township, and from this point roads extend west to Lavant station on the Kingston and Pembroke railway, and north through Lavant township. To the south a road extends also to the foot of Dalhousie lake connecting with other roads which traverse the north-west portion of the township. On the road west to Lavant station the rocks for some miles, or almost to Robertson lake, which is in the south-west corner of Lavant, are mostly reddish and granitic or dark coloured and hornblendic. A band of crystalline limestone crosses this road at a stream on the township line where there is a mill, about midway between the village and Robertson lake. The limestone does not extend far to the east as it is not seen on another road leading north from Poland, being apparently cut off by a mass of the greenish-black hornblende rock which has an extensive development in this direction. To the south-west, however, it may be continuous with a band of limestone which appears on the Lavant mill road south of Robertson lake, and which may be the north-east extension of one of the bands seen to the east of Snow road station. A second band appears on the road to Lavant station a short distance east of the lake at Lavant post office. This band extends past the south end of the lake, beyond which point it has not been traced.

Robertson lake.

The shores of Robertson lake on the west side are composed entirely of ordinary reddish granite, which in places shows foliation, but is generally massive. This appears to be the eastward extension of the great area of granite-gneiss already referred to as occurring around the shores of Gull and Croche lakes and which occupies the northern portion of the township of North Sherbrooke. The granite extends west of the lake to the forks of the road leading to the Wilbur iron mine, along which it is well seen to the eastward in a prominent ridge, but beyond this point the schists and associated limestone come in and extend to the Kingston and Pembroke railway. The schists in this part of the section are often highly micaceous.

Lavant mill-road.

On the Lavant mill-road from Robertson lake south, to the head of Dalhousie lake and on a branch road leading thence to Snow road station, almost continuous exposures of black hornblende rocks, with masses of red granite, are seen. About midway a band of limestone comes in with a breadth of several hundred yards which may be the extension westward of the band referred to on the road west from Poland, though its connection has not been traced. Along the north side of the Mississippi river, east of the Snow road crossing, limestones are exposed but these are much broken up by masses of granite and diorite and their distribution is very irregular. The northern portion of North Sherbrooke may be said to be largely occupied by masses of granite and hornblende rocks in which small areas of limestone are sometimes seen, but these are usually highly altered and have an abundance of disseminated quartz.

Area south of Poland.

On the roads traversing the central portion of Dalhousie, south of Poland, the same black hornblende rocks, associated with granites, are predominant. Several small bands of limestone were noted in this area but their distribution is evidently local since they cannot be traced to any considerable distance in either direction. The southern part of this area, in the vicinity of Patterson lake, and to the north of it is apparently occupied largely by the red granites to the contact with the limestone area already noted as extending along the road from Dalhousie lake to Watsons corners.

Area north of Poland.

North of Poland village, the roads thence into Lavant township as far as Clyde forks, and thence east to the Darling road, show a considerable development of hornblende rocks. In places these consist of massive diorites with areas of schists, and occasionally there are masses of red granite. Bands of dolomite, sometimes very ochreous on weathered surfaces, occur, and sometimes these are filled with strings and bunches of white quartz; but the eastern half of this township is largely occupied by the rocks of the hornblende series. Indications of ores of several kinds are found at different points, including iron, copper, etc., but much of the district is unsettled and has never been thoroughly prospected for economic minerals.

Calabogie to Brightside post-office.

A good section is afforded by the road which traverses the townships of Bagot and Darling from the east end of Calabogie lake to Brightside post-office, formerly La Rocques corner. Near the lake the rocks along the road are limestones with schists of several kinds, and occasional masses of diorite on either side, in which are located several of the iron mines of the Calabogie area. These ores have been mined at intervals for some years. A mass of red granite comes in near the cross road about one and a half mile south of the bridge over the Madawaska river and has a breadth of several hundred yards. This is followed southward by black hornblende schists with diorites for a couple of miles to a small lake on the west side of the road. Here a band of dolomite, containing an abundance of quartz in strings and bunches, crosses the road and extends west for a mile or more into the unsettled country. This band has a breadth of about half a mile, and is again succeeded by similar hornblende schists and diorites as before with a breadth of a mile, to a somewhat extensive area of the quartz-bearing dolomites which comes from the vicinity of White lake on the east. This dolomite area is exposed along the roads for nearly three miles and extends across into Darling township. The band apparently

White post-office.

dies out a short distance west of this road, and thence to White post-office, the rocks are a succession of these quartz-bearing limestones with bands of hornblende rock which sometimes are true schists. Occasional masses of red granite are seen, but the rocks as a whole are distinctly hornblendic. The strike of these is uniformly to the north-east, the dip not always easily determined. South of White post-office diorites and granites extend for about three miles, with one or two narrow bands of dolomite, but at this point a somewhat broad area of limestone comes in which extends thence nearly to Brightside, or to the road north of that point which leads across to Tatlock. This limestone is the usual striped variety with bands of grayish rusty gneiss and has a south-east dip. Near Brightside it meets an area of granite which is well exposed along a road which follows the township line in the direction of Clayton. The limestone band just indicated continues north-east to Tatlock where it crosses a road leading north, with a breadth of about two miles, and is thence continuous into MacNab as part of the great calcareous band of that township. North of Tatlock it is separated from the large area of White lake by a belt of green diorite or chloritic rocks, which extends to near the end of the long south-east bay of that lake in the township of Darling.

White lake.

The north-east part of this township is intersected by White lake which extends south-west from White lake post-office in the southern part of MacNab. The south-east side of this lake is marked by several deep bays and large exposures of the striped limestone are everywhere visible. This is terminated westerly by the great mass of the hornblende rocks described as occurring on the road south from Calabogie. The north side of the lake is occupied by a heavy mass of generally reddish granite, which occupies the south-east corner of Bagot. East and north of this lake the limestone spreads out and continues into the townships of Pakenham and MacNab till it is overlain by the Black River limestone of the Ottawa basin or by the Calciferous and Chazy formations of Arnprior and Sand Point. The strike of the crystalline limestones at White lake post-office is N. 60°–70° E. and the dip is north-west <60°–70°.

White lake to Arnprior.

The roads from the foot of White lake at the post-office continue north-east to Arnprior, and north-west to Burnstown on the Madawaska river. Along the latter the limestones are exposed almost continuously to the cross roads half a mile south of the river, where the dip becomes reversed to S. 15° E. <80°. Here, thin bands of gneiss and schist are associated, and the limestone area practically disappears when the river is crossed at Burnstown, giving place to black hornblende rocks and schists with areas of reddish granite. On the continuation of this road to Renfrew the limestone does not appear, or but slightly, till within a couple of miles of the latter place, where a band several hundred yards in width crosses the road in a north-east course, and continues on its strike to the line of the Canada Atlantic railway. The rocks along this road to Renfrew dip S. 20°–30° E the dips ranging from < 30°–90°.

Area south of Renfrew.

From this road another turns off west about midway between Burnstown and Renfrew, and traverses the south-east corner of Bagot, crossing for the most part an area of red granite, which is often coarse and without foliation. This road extends across to one which connects the villages of Springtown and Burnstown, along the north side of the Madawaska river, and no limestone was observed in this direction.

On the road north-east from the foot of White lake to Arnprior the same area of crystalline limestone is seen for a distance of about one mile and a half. The road descends in this distance from the height of land at the lake to the great flat area south of Arnprior which is occupied in part by Black River limestone, but here the rocks are mostly concealed by a great covering of clays. All these limestones are of the striped variety and they again appear in the town of Arnprior, from beneath the mantle of Calciferous limestone, where they are extensively quarried for lime-burning and for building stone.

Blythfield and Canonto.

A somewhat important area of this limestone is also found in the north-west part of the township of Blythfield, to the west of Calabogie lake, where it has a breadth in places of nearly two miles. From the west end of this lake it can be traced in a curving outline, south-west across the Madawaska river into North Canonto, and it is probably connected there with the outcrops which have been described as occurring on the shores of Mud lake, in the Madawaska river section, where however this rock is interstratified with heavy bands of gneiss. North-east from Calabogie lake it extends across the corner of Bagot into Admaston, where it is associated with schistose and hornblende rocks, and thence, continuing north-east, reaches the Ottawa river below the village of Portage du Fort, where it becomes much disturbed and sometimes entirely cut off by masses of anorthosite and of red granite on the north side of that river. The limestones along this part of the Ottawa are associated with bands of rusty grayish and black gneiss which are identical with those seen with the limestones of the Grenville district, the rocks of the two sides of the river being identical in many respects and the strata continuous. While the strike of these rocks is to the north-east, they present minor variations

Anorthosite of Portage du Fort.

and are also thrown into several folds as though the strata were displaced by the agency of intrusive masses of granite and anorthosite, the latter rock appearing in a large mass, several square miles in extent, to the south of the village of Portage du Fort, in the northern part of the township of Horton. This area of limestone is separated from that of the White lake basin by a great mass of granite-gneiss in MacNab township which appears along the line of the Canada Atlantic railway between Renfrew and New Glasgow and for some miles on either side, and which occupies the country to the foot of the Chazy and Black River ridge south of Sand Point, which is on the shore of the Ottawa about five miles west of Arnprior.

Syncline.

The synclinal character of the large limestone basin of White lake and the lower Madawaska river is seen by the reverse dips of the strata at Stewartsville, which is north of the river, where dips are well defined to the south. The strike is here deflected to the east and even to the south of east as if by the agency of the granite mass already referred to along the Canada Atlantic railway east of Renfrew. In this respect the structure of this basin resembles that already noted as prevailing in the areas to the south and west as also at points along the north side of the Ottawa; and it may be generally stated that this synclinal feature is general throughout the greater portion of the area under consideration.

Ramsay.

In the township of Ramsay the broad belt of crystalline limestone which occupies the greater part of Lanark adjacent on the west, has its northern margin near the village of Clayton in the north-west angle of the township. To the west of this in the north-east part of Lanark the strike of the limestone suddenly changes from its usual course of N. 60° E., to S. 50° E. with a south dip, as if deflected against the great mass of red granite which occupies the north-west part of the township of Pakenham. The contact of the limestone and gneiss follows closely the road east from Clayton towards the Mississippi river and maintains a south-east dip for some distance; but to the south of this a reverse dip to the north-west is seen at several points, while several minor folds occur in the centre of the basin itself.

General structure of the limestones and schists.

The distribution of these several formations of gneiss, limestone and granite can be best seen by reference to the map. It would appear from the examination of these rocks, over widely separated areas, that there is a marked resemblance at many points, and that in fact most, at least of the limestones and associated schists, with gneiss, are repeated from point to point, forming basins of approximately the same horizon. In all cases the limestones present practically the same striped or banded aspect so common to these rocks in the Hastings series, except where this feature has disappeared through a greater metamorphism of the strata, when they become less definitely marked and assume the characteristics of the limestones of the typical Grenville district. This more highly crystalline condition appears to be more strongly marked on the whole, as the Ottawa river is approached, and, while the different strata of limestone, rusty gneiss, and sometimes the schists, can be traced directly across the Ottawa, the striped character of the beds is rarely there noticeable. The peculiar aspect of the limestones containing quartz, so frequent in these rocks to the south of the Madawaska river is rarely seen north of the Ottawa and these indications of metamorphism, as also their tremolitic character, would therefore appear to be due rather to local causes than to wide areas of regional alteration.

Ridge south of the Ottawa.

A somewhat prominent ridge of these old crystalline rocks, separated from the main mass already described by a great intermediate basin of Palæozoic strata, is seen to the south of the Ottawa river east of Arnprior, in the towships of Fitzroy, Torbolton, Huntley, March and Nepean. It does not appear on the south shore of the Ottawa, since it is concealed in that direction by the overlying beds of the Potsdam, Calciferous and Chazy formations, while the overlying beds on the south, in the valley of the Carp river, are mostly of Black River and Trenton age.

Chats falls.

The rocks of this old ridge are largely reddish gneiss with granite, some of the latter being apparently of quite recent date, since in the township of Nepean they are seen to cut or alter the overlying beds of the Potsdam sandstone at one point at least. In the western portion of the ridge near Fitzroy Harbour, there is a large development of crystalline limestone which presents similar features to the limestones already described in the areas further to the west, in the presence of scales of mica and graphite as also of chondrodite, and of rather indistinct lines of banding. They are in this vicinity penetrated or invaded by masses of granite, sometimes in the form of dykes of large size, and this feature can be well seen at the Chats falls, where a large mass of this granite crosses the river, cutting the limestone and forming a huge barrier over which the water of the Ottawa river falls. To the north of the Chats falls, masses of green hornblende and schist rocks are found which contain quartz veins and masses, in which explorations for gold have been carried on. Detached areas of the limestone are seen at various points in the ridge of these crystalline rocks, but cannot be traced continuously to any considerable distance. They appear to be cut off in places entirely by granite masses. North of Carp village

Gold.

Carp and South March.

on the road to South March, there is a considerable development of highly quartzose dolomite limestone, which is like much of that seen in Darling township. The eastern portion of this ridge is more granitic, and large dykes of pegmatite are visible. Well defined garnetiferous gneiss is, however, seen at some points and good exposures occur 150 yards west of South March station, where the strike is well defined with an east and west course and a south dip < 75°. Masses of dark, often coarse, diorite are seen in the vicinity in which irregular deposits of dark mica are common, but the mineral here is of but small economic importance. Similar black micas are seen to the north of the village of Carp and have been worked to some extent. Near South March station also several narrow bands of the limestone are found which are cut by pegmatite dykes, and these contain at one point deposits of graphite in small quantity. Portions of the pegmatite are highly felspathic and might be worked to some extent for economic purposes. The eastern extremity of this ridge in March and Nepean townships is overlain by sandstones of the Potsdam formation, the transition between this and the Calciferous limestone being well seen at a number of places.

ECONOMIC GEOLOGY.

Economic minerals.

Very full details of the principal economic minerals found in the area included in this report have already been given in the several reports by Mr. H. G. Vennor, extending from 1871 to 1876. Some additions must however be made to this list as there described, owing to more recent investigations and developments.

The chief minerals of economic importance include iron, gold and silver, galena, nickel, mica, apatite, graphite, corundum and feldspar, and among other important economic products may be enumerated building stones, bricks and tiles, dolomites, shell-marl, lime and peat.

Iron mines.

The most largely distributed of these in this area are the deposits of iron which are found at a number of widely separated points. Many of these are found in close proximity to the line of the Kingston and Pembroke railway, which connects the town of Renfrew with the city of Kingston. These deposits have recently been very carefully studied by Mr. Ingall,* of this department, and his report on the subject contains full descriptions of all the important mines in the district. It will be necessary therefore in this place merely to refer to the principal localities where these ores are found.

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* Annual Report, Geol. Surv. Can., Vol. XII, (N.S.), part I.

Among these may be mentioned the Bygrove and Fournier mines, the former on lot 3, range I, South Sherbrooke, the latter on lot 14, of the same range. These have also been described in Vennor's report on the area for 1874-75, pages 122-123; and the Christys lake mines on lots 18, 19 and 20, range III, and lots 17 and 18, range II, of the same township, also referred to in the same report on page 120, and in that for 1872-73, on page 174.

In the township of Bathurst, the Foley mine is situated on lots 10, and 11, range VIII. In Dalhousie township, the Dalhousie or Playfair mine is on the east half of lot 1, range IV, and is described also in Vennor's report for 1872-73, page 176.

In South Sherbrooke township also, near the shore of Silver lake, several openings have been made on lots 14, 15 and 16, range IV.

Along the line of the Kingston and Pembroke railway, the Robertsville mine is located on lot 3, range IX, of Palmerston, township the Wilbur mine on lot 3, range XI, of Lavant township, and the Caldwell and Radenhurst mine on lot 22, ranges III and IV, near Flower station.

About Calabogie lake several mines have also been opened, and worked quite extensively, on lot 16, range X, township of Bagot, and and on lot 16, range VIII, and several practically undeveloped areas are found between the Madawaska river and Norway lake. To the south-west of the White lake is the Yuill mine on lot 25, range V, Darling township, and on the south side of the lake are Bell's mine on lots 23 and 27, range XI. The Robertson mine is on lot 1, range I, also of Bagot.

Character of the ore.

The ore from most of these mines is magnetite. In places this contains pyrites in small quantity and the ore is in consequence somewhat sulphurous, but much of the output is comparatively free from this ingredient and the mineral is correspondingly valuable. In the Dalhousie mine the ore is hæmatite and this also is found at Bell's mines on White lake, where both the red and black iron ores occur. The value and extent of this last named deposit has apparently never been thoroughly tested.

Near the village of Dacre in the north part of the township of Brougham, a deposit of magnetite is seen which has recently been quite extensively worked by the Canada Furnace Co. It is about half a mile south of the cross-road at that village. In the town of Arnprior a deposit of hæmatite was worked some years ago. It apparently occurs along a line of fault between the crystalline limestone and the Calciferous dolomite. The deposit at this place is said to be nearly exhausted, but the mineral occurs at several points along the line of a fault in a south-west direction from the old shaft.

In the township of Grattan, on lot 16, range IX, and on lot 17, range X, a large deposit of magnetite is now being opened by the Canada Iron Furnace Co., of Montreal. The location is about four miles south of Caldwell station on the Canada Atlantic railway, and appears to be quite extensive, several thousand tons having been already extracted.

Mode of occurrence.

Generally speaking, these ores occur in connection with crystalline limestone, though sometimes in granite or diorite masses. Eruptive rocks are frequently found in close proximity to the ore bodies, which are often pockety in character, and in some places they are in connection with the eruptive rocks entirely.

The Dalhousie or Playfair mine appears to occur altogether in the crystalline limestone. A full description of this deposit is given in Mr. Ingall's report, 1901, page 70 I.

GOLD.

Gold.

The known deposits of gold in this area are few. The mineral has, however, been found at several places, and mining has been carried on quite extensively for some years, notably in the township of Clarendon, Frontenac county, between the villages of Plevna and the Mississippi river at Ardoch.

Clarendon.

Two mines are here located, viz., the Webber, on lot 28, range VIII, and the Boerth mine on lot 28, range VII. At the former place little actual mining work has been done, though a stamp mill was erected on the property some years ago. The ore is found in small irregular strings of quartz associated with reddish gneiss and granite which cuts the crystalline limestone of the Long Lake area on the Mississippi river. At the principal opening a dyke of diabase cuts the rock, and the quartz veins appear to be connected with this intrusion. No reliable information is available as to the actual results obtained from the operations at this place, and only a limited amount of development work has been done, probably owing to lack of capital on the part of the owners. The quartz, however, carries gold in small quantity.

Boerth mine.

The Boerth mine was started several years ago on the lot adjoining the Webber property on the east. It is near the road leading from Ardoch to Plevna. Here the veins are evidently larger and apparently carry a larger percentage of gold. A stamp mill and concentrating plant were erected and a large amount of money was expended in the attempt to extract the gold from the ore, though but scanty information is available as to the actual results obtained. Mr. Walter Wells, the provincial assayer of Belleville, states that the percentage of gold in portions of the quartz is fairly high. but that the ore is very refractory.

Denbigh.

In the southern part of the township of Denbigh, gold has been reported from several points. No definite exploration has, however, as yet been carried on in so far as can be learned, though some blasting work has been done. The rocks in the area are mostly granite and gneiss with some diorite with which the small quartz veins are associated. Near Eagle hill, also at Fergusons corner, a small opening was noticed in a quartz vein which was said to carry gold, but none was visible in the rock and no work has been done here for some years. The similarity of the rocks in this belt to those which occur in the Madoc and Marmora area is easily recognized, and the mines referred to are apparently in the north-east extension of that belt.

Griffith.

Further north also in the township of Griffith, gold has been reported as occurring in quartz veins situated to the east of the road from Griffith bridge to Dacre, but no satisfactory information as to the nature of the deposit has yet been received. In the southern part of the township of Lavant, a small percentage of gold was also found in an assay of ore from lot 12, range IV, in connection with copper. The ore is pyritous, and occurs in a band of limestone near eruptive rocks. A shaft was sunk to a depth of 70 feet but no details as to results are available.

Lavant.

An assay of quartz, by Dr. Hoffmann, taken from the west half lot 10, R. VI, Lavant, Lanark Co., yielded 0·195 oz. of gold to the ton, and a white quartz carrying small quantities of copper and iron pyrites and some galena from the N.E. portion of lot 12, range II, South Sherbrooke was found, (Ont. Bureau of Mines, 1901, p. 204) to contain 3·500 oz. of gold to the ton, and 0·428 silver.

It seems probable therefore that gold will be found at a number of points in this district, under conditions somewhat similar to those which prevail in the Marmora area. The presence of masses of intrusive granite and diorite through the associated hornblende rocks and crystalline schists, which have a wide distribution, is supposed to be favourable to its occurrence, but the results so far have not been commercially successful. The ore is largely pyritous rather than free-milling, so that expensive methods of treatment may be necessary for its extraction.

SILVER AND GALENA.

Silver and galena.

Deposits of these minerals occur at several places in the map area, notably in the township of Barrie, and principally in connection with the belt of limestone and dark hornblende rocks which extends from the west end of Long lake, on the Mississippi river, along the road from Myers Cave post-office to Ardoch. This road keeps along the narrow strip beneath this lake and lake Missasagagon to the north. Several openings have been made on the upper or west end of Long lake at the portage to Whitefish lake, which is a short distance south of Perry, but the ore indications at this place are small. The rocks consist largely of crystalline limestones which have been altered from the bluish slaty limestone of the area, apparently by the agency of the granite masses in the vicinity. This place is known usually as Myers cave.

Barrie.

Along the road to Ardoch, however, on lot 12, range VIII, Barrie, a shaft was sunk some years ago on a band of silver-bearing galena, portions of which on assay gave a fairly high percentage of silver. Work was discontinued at this place owing to litigation as to ownership of property, and at the time of visit the shaft could not be examined. The country rock is a crystalline limestone with bands of black hornblendic slaty or schistose gneiss. This formation continues eastward across the township, and the gold mines north of Ardoch are practically on its extension. Several assays of the ore from this place were made in the laboratory of the Geological Survey, the percentage of silver, in one case from a sample from lot 12 of rather coarsely crystalline galena, being 137·883 ounces to the ton of 2,000 pounds and a trace of gold, while a sample from lot 9 of the same range gave 119·583 ounces of silver to the ton but no gold.

Assays.

A number of assays have been made from time to time by Dr. Hoffmann from other places in the area of the map-sheet, and for the sake of convenient reference these have been collected from his reports and are here inserted.

Darling.

In the township of Darling, Lanark county, on lot 19, range III, an assay of quartz from a vein gave neither gold nor silver. One from lot 25, range V, same township, gave a trace of gold but no silver. Another from the west half of lot 22, range IV, gave 0·111 of an ounce of gold and 5·176 ounces of silver.

Lavant.

In the township of Lavant, on lot 10, range VI, a rusty pyritous gneiss yielded at the rate of ·175 ounces of gold and no silver. Another assay of a sample from the east half of lot 12, range IV, from a pyritous dolomite, gave a trace of gold, and one from the east half of lot 12, range II, South Sherbrooke, from a quartz vein containing pyrites and galena, gave gold at the rate of 3·50 ounces and silver 4·08 ounces to the ton of 2,000 pounds.

Clarendon.

In Clarendon township, Frontenac county, a sample of quartz from lot 28, range VIII, gave 2·098 ounces of silver to the ton but no gold; one from lot 26, same range, neither gold nor silver; samples from lot 35, same range, neither gold nor silver, and like results from samples from lot 38, range X. A sample of quartz from lot 26, range IX, of the same township, with galena gave silver at the rate of 59·662 ounces, but no gold. Samples from lot 34, south-west concession of Frontenac road, from quartz containing pyrites and pyrrhotite, as also similar samples from lot 32, range XI, and from lot 42, north-east concession, gave neither gold nor silver.

From the above assays of specimens from different places in the township just mentioned, there would appear to be an area of considerable extent in which a well defined mineral bearing zone exists and in certain portions of which the prospects for profitable mining may be reasonably expected. The greater part of the ore is, however, associated with pyrites in so far as the gold is concerned, so that the extraction is, as a rule, somewhat difficult and probably expensive.

Carleton Place.

In the Geology of Canada, 1863, reference is made to a mine in the township of Ramsay, a short distance west of Carleton Place, which was opened on a vein of galena, cutting a grayish dolomite of Calciferous age. The galena occurs with iron and copper pyrites associated with blende in a gangue of calc-spar. Work was carried on for some time at this place about forty years ago, and a smelting furnace was erected. A considerable quantity of the ore was raised, but the smelting was found to be unprofitable, and the vein appeared to terminate when the underlying Potsdam sandstone was reached. Operations were abandoned many years ago and the works have fallen into decay.

Fitzroy.

" Galena also occurs in the township of Fitzroy, near the road leading from Galetta to Fitzroy harbour. A lead-bearing vein was opened on the 20th lot of range VIII, having a width of six inches, cutting crystalline limestone, but it has apparently never been worked. On Laflammes island, below the head of the Chats rapids, on lot 26, range VI, there is also a deposit of galena, known as Robertson's mine, which was opened some years ago and worked to some extent. The ore is disseminated in a calcite vein in crystalline limestone, near a large dyke of red granite, and carries but little silver. The shafts have long been filled with water, and nothing has been done at this place for a number of years.

GRAPHITE.

Graphite.
Black Donald mine.

Graphite is found in connection with the crystalline rocks at a number of places in workable quantity. Of these the most extensive deposit is that in the township of Brougham, lot 18, range III, on the south-west side of Whitefish lake. The country rock is a crystalline limestone which is cut by dykes of red granite. The graphite is in the form of a large bed or bedded vein, ranging from six to over ten feet in width at the surface, and following the strike of the gneiss and limestone which has a course of N. 45 E. with a dip to the south-east of 60 degrees. The mineral is underlaid by a hard pegmatite dyke and the vein increases in width as a greater depth is reached. In places the mineral is found on both sides of the dyke, and the mass of ore extends out under the water of the lake. This dyke also holds scales of graphite, which is rarely disseminated throughout the gneiss of the vicinity. The dyke is evidently more recent than the gneiss and limestone and has altered these along the line of contact. Iron pyrites occurs also in the gneiss along the contact with the granite. This ore has been worked for some years and extensive works have been recently erected for preparing the ore for market, power being obtained from the Madawaska river which is in close proximity to the mine. The ore is largely of the amorphous variety but a flake structure is seen in portions of the bed. The output is hauled to the Kingston and Pembroke railway at Calabogie lake. For details see "Bulletin on Graphite." A similar deposit is seen in the township of Darling, near Tatlock post-office, but does not appear to be so promising. It has as yet not been opened.

Olivers ferry.

Near Olivers ferry, on the Rideau canal, on lot 21, range VI, North Elmsley township, a deposit of flake graphite occurs in a gray gneiss and limestone. The location is about three-fourths of a mile from the shore of the river. The property was worked to some extent a number of years ago and a plant for the separation of the mineral was erected on the bank of the canal at the Ferry. Recently work has been resumed with a good prospect of success, as the mineral forms an extensive deposit and is convenient for shipment.

High falls, Madawaska.

At a number of points throughout the district, graphite occurs as disseminated scales in the crystalline limestone, but such occurrences are of no economic importance in so far as yet recognized. Above the High falls on the Madawaska river, on lots 13 and 14, range IV, Blythfield township, on property owned by Mr. James Bailey, an opening has been made in a gray gneiss. The mineral appears to be in fair quantity, though but little work has been done towards its development. Some work has also been done on a deposit of this mineral on Con. II, South Canonto, the extent of which is as yet unknown.

MICA.

Mica.

The occurrence of this mineral in the pyroxenic rocks near the lower portion of Rideau lake, in the township of North Burgess, has been known for many years. Extensive mining for apatite was carried on in this district over thirty years ago, the details of the different mines being given at some length in the reports by Mr. H. G. Vennor for the years 1873–74 in connection with his notes on the occurrence of apatite in this district. Mica almost invariably accompanies the apatite in all the mines of the area, but at that date was regarded simply as a waste product. The same association of the two minerals is recognized at many of the mining locations north of the Ottawa, and here the proceedings are reversed, the mines now being worked for mica only, while the apatite is saved as a by-product.

North and South Burgess

Probably the first reference to the mica of this district is found in the Geology of Canada, 1863, pages 494 and 795. It is also referred to in the report by Mr. Gordon Broome, in the volume for 1870-71, page 321. Mica has been mined quite extensively in the township of South Burgess, on the south side of Rideau lake, some of the shafts reaching a depth of over 100 feet, from which a large amount of excellent mica was obtained. Several of the mines in North Burgess have also been operated during the last ten years, but no information as to output is to hand. The conditions under which the mineral occurs at all these places, are identical with those found in the areas north of the Ottawa river and described in the report on the Grenville sheet, Part J, Vol. XII, 1899.

Claendon.

In Clarendon township, lot 24, range II, a deposit of white mica has been worked irregularly for some years. The mineral, however, is affected by inclusions of iron which render much of the output useless for electrical purposes. In the vicinity of South March station, on the Canada Atlantic railway, and also near the village of Carp, further west, there are several irregular deposits of a very dark variety which have been opened up, but as yet not worked largely.

Mines of Rideau area.

A number of mica mines occur in the townships of North and South Burgess, some of which have been extensively worked for a number of years. Among these in North Burgess may be mentioned the Hanlan mine, on lot 2, range VI; the Martha mine, on lot 13, same range; the Baby mine, lot 2, range V, on the south side of Long lake; the Byrnes mine on lot 11 and east half of lot 12, range VII; the Watts and Noble mine, on lot 4, range IV; the Pike Lake mine on lots 16 and 17, range IX, near Stanleyville, the product being largely muscovite; the Blackhall mine on lot 10, range V; the McNally mine on lot 21, range V; the McLaren mine on lot 4, range VIII; the McMarten mine on lot 1, range VI, and the Munslow mine on lot 13, range VI. In South Burgess, the Canton mine on lot 1, range IV, and the Downey mine on lot 7, range I. The Bliss mine is in South Burgess, about 12 miles south-east from Perth by road; the Blair mine on lot 3, range IX, Bathurst, and the Gibson mine on lot 25, range IX, North Elmsley. On some of these properties a large amount of work has been done and much mica of good quality extracted. The area in North Burgess shows a large development of pyroxene rocks in which both apatite and mica occur and the district has been known as a mining centre for over thirty years. Most of these mines were examined in 1901, and the conditions seen were similar to those which prevail in the mica district north of the Ottawa. Work is still being carried on at several of these locations. For further details see "Bulletin on Mica."

APATITE.

Apatite.

The distribution of the principal apatite deposits in North Burgess, where this mineral is most abundant, is given in the reports of Mr. Vennor already alluded to. Work was carried on in this area for a number of years and there is a large district north of the Rideau lakes where the mineral occurs in sufficient quantity to be of economic importance. Unfortunately the decline in the price of apatite, by which the mines of the Ottawa district were obliged to suspend operations some years ago, has affected all the mines of the area under discussion, and the only production now is merely as a by-product from the mining of mica.

In the township of South Sherbrooke, lot 11, range VII, crystals of good size are obtained from calcite veins in pyroxene, but the locality has never been a producer, and as a rule it is found that the occurrence of apatite crystals in this mineral only rarely reaches the economic stage of production.

CORUNDUM.

Corundum.

Though the principal deposits of this mineral are found in the area comprised in map-sheet, No. 118, adjoining the present one on the west, the corundum bearing belt of rocks has been traced eastward from this area, which abuts on the Madawaska river near the foot of Kaminiskek lake and crosses the river at the Palmer rapids a few miles below, into the township of Lyndoch and thence into Sebastopol and Brudenell in the direction of Clear lake. The belt also extends into the adjacent township of South Algoma which lies just north of the limit of the map sheet. The mineral itself has not, however, been found as yet in écomonic quantity east of the Madawaska river.

In the southern portion of the area similar rocks carrrying corundum have been recognized in the southern part of the township of South Sherbrooke, and also in North Crosby and North Burgess, but the explorations so far carried out in this direction have not so far revealed its presence in sufficient quantity to warrant large expenditure in the present condition of the market for the material.

COPPER.

Copper.

References to the occurrence of copper at various points in the area under discussion are found in several of Vennor's reports, more especially in that for 1874–75. From the descriptions there given it would appear that a somewhat broad belt of copper-bearing rocks is found extending from the south-east corner of Palmerston township through Lavant and into Darling, in which copper ore is found in a number of places. These are well described on pages 161–162 of the report referred to and need not be repeated here.

Considerable development work has also been done at the Helena mine on lots 19–20, range VI, and lot 20, range VII, Barrie. The ores are copper and gold in a quartz vein, cutting crystalline limestone, but operations have been suspended since 1901.

DOLOMITE.

Dolomite.

Quite recently there has been a considerable demand for this mineral in connection with the manufacture of chemical wood-pulp. Magnesian limestones suitable for this purpose occur at a number of places some of which could be readily utilized. Among these may be mentioned the following:—

On lot 22, range VIII, Lanark, a limestone with 42·10 per cent of carb. of magnesia. In Dalhousie township, lot not named, a similar rock with 42·63 per cent, and on lot 27, range IX, Barrie, a limestone with the same proportion of magnesia as the last-mentioned.

On lot 10, range IV, of Aldfield, in the province of Quebec, but not in the limit of the present map-sheet, a dolomite is found with 46·01 per cent of magnesia.

In the township of Ross, lot 19, range VI, a large area of very pure dolomite, giving over 40 per cent of carbonate of magnesia occurs. On lot 9, range XIV, township of MacNab, a calciferous dolomite gives carb. of lime 53·00 per cent and carb. of magnesia 43·88 per cent, see Report 1876–77, p. 486. This is near the Ottawa, about two miles west of Arnprior.

BUILDING STONE.

Building stone.

The limestones of Black River age, as also of the other formations to the top of the Potsdam sandstone frequently yield stone well adapted for purposes of construction. Among the sandstones of Potsdam age the large quarries in the western part of the township of Nepean have already furnished a large amount of the material used in the Parliament buildings at Ottawa, while certain portions of this rock are sufficiently free from iron to be employed for glass making. Unlimited quantities of this rock are available in the areas to the west of Ottawa in the western part of the great Ottawa River basin.

Limestones

The Calciferous dolomite has also been somewhat extensively quarried for building stone at a number of points. Large quarries of this rock of a brownish colour are found near Carleton Place, on lot 20, range IX, Ramsay. A fine white sandstone also occurs at this place. There is also a quarry on the south side of Otty lake near Olivers ferry, the stone being used for the Tay canal.

In the Chazy formation, in addition to the limestones available for building stone and lime burning, certain bands occur which have been somewhat largely used for the manufacture of cement, as in the case of the Wright quarries near Hintonburg. This band lies near the middle of the formation or at the base of the upper or calcareous division.

The Trenton limestones are too well known to require further description. Good bands are found wherever the formation occurs.

Among the crystalline limestones, those of the Hastings series furnish large quantities of fine material both for lime burning and for construction purposes. Among the largest quarries may be mentioned those of Renfrew and Arnprior, but there are large areas of good material at a number of places, only the distance from convenient shipping points being against their present development.

Granites.

Many of the granites and granite-gneisses would also furnish an excellent stone or building purposes, but except for local use and on a small scale, these have not yet been utilized.

Felspar.

Felspar, which forms a large part of many of the pegmatite dykes and masses so numerous in the crystalline rocks is of value for the manufacture of pottery and for some of the grades of porcelain. The cost of transport is, however, in most cases too great to render it at present economically available, unless where the material occurs in close proximity to lines of railway. The percentage of pyrite in some of this rock seriously affects its value.

Brick clays.

Brick clays are widely distributed throughout a large part of the area, especially in the Ottawa and Rideau basins. They are quite extensively used for the manufacture of bricks and drain tiles. Several important works in this line are found in the broad belt which extends through Huntley, MacNab, Torbolton and Fitzroy townships, as also in the vicinity of Olivers ferry and Smiths Falls.

Shell-marl.

Shell-marl is abundant in the bottoms of some of the lakes, but often too far removed from points of shipment to be of much value except locally. As a fertilizer it is very rarely employed by the farmers of the districts where it occurs. Among lakes which contain this material in quantity may be mentioned White lake in the south part of McNab, Mink lake in Wilberforce, Otter lake in South Elmsley and several lakes in Brougham and Matawatchan. Little attention has however, been directed to these deposits, though the manufacture of hydraulic cement, in which this material is now largely used, may serve to make some of them valuable in the near future.

In the township of Lavant, lot 13, range IV, a deposit of marl also occurs said to cover six acres and having a depth of about seven feet.

BISMUTHINITE.

Bismuthinite.

The mineral bismuthinite is known to occur in some part of the township of Lyndoch in small quantities, but the exact location of the deposit has not yet been disclosed. It has also been found in a quartz vein in small quantity on lot 33 in the south-west range, Clarendon, and on a lot to the north of Buckshot lake, in Miller, but no details of these are to hand.

NICKEL.

Nickel.

This mineral has been found in connection with pyrrhotite in the township of Dalhousie. The occurrence is on lot 18, range III, where a considerable deposit of the latter mineral occurs in a large mass of dioritic rock associated with granite which cuts gray gneiss and limestone. The analysis of the pyrrhotite gave 0·165 per cent nickel with a trace of cobalt, and another deposit on the east half of the same lot gave 0·09 per cent of nickel. The amount of nickel at this place would appear to be too small for economic extraction, and the remoteness from lines of railway is also against the present profitable development of the property.

PEAT.

Peat.

Although peat-bogs are found at a number of points in the area, many of these have not as yet been tested as to depth or quality of the material. Among those most conveniently situated for exploitation may be mentioned a bog on lots 5, 6 and 7, ranges VI and VII, Beckwith township, which has been sounded to a depth of over thirty feet. It is in places only one mile distant from the Canadian Pacific railway.

Two other bogs also occur in this township one on lots 17, 18 and 19, along the road between ranges III and IV, with a proved depth of from four to seven feet. This is four miles and a half from the line of the Canadian Pacific railway, and the other is found on lot 15, range VI, of the same towship.

A large bog occurs in Huntley township, extending over lots 1 to 10, on ranges IX and X, and crossed by the road south from Huntley post-office to the line of Ramsay. The depth of the deposit has been proved at a number of points and found to range from eight to fifteen feet where no bottom was reached. The latter depth is found on the middle of range IX and in the north half of range X. This deposit is in places underlaid by white marl.

In Goulbourn township south of the village of Richmond, a large bog also occurs, which extends into the township of Marlborough. The depth of the deposit has not yet been proved.

GLACIAL GEOLOGY.

Glacial geology.

Indications of ice-action and of subsequent submergence are visible at many places throughout the area embraced in the map-sheet. Glacial striæ are frequent and show great divergence in direction, and there are large areas of clay and sand in which marine shells are occasionally found, though their presence is much less frequent than in the district nearer the St. Lawrence and the lower Ottawa rivers.

Lists of all observed stri ae have been prepared and are here appended The course of these tend to show that possibly there were several periods of ice movement and that they were sometimes caused by floating ice as well as by the action of glaciers. Occasionally widely diverging striæ are seen on the same exposure.

Gravel ridges.

Ridges of gravel and boulders were noticed at several points. In some of these, notably at the large ridge at Carp station on the Canada Atlantic railway, now, however, mostly removed for ballast, marine shells were very abundant. In other ridges these were not observed. The position of some of the most important of these and their direction are given in the list of striæ. One of the most interesting of these ridges is seen about three miles north of Smiths Falls, near Welsh's siding, where a prominent ridge of gravel crosses the road in a north-east direction. From this locality the bones of a whale were obtained some years ago, the elevation being about 440 feet above sea-level.

Marine shells.

In the large area of clay to the west of Renfrew no marine shells have as yet been found. These organisms are apparently for the most part confined to the overlying gravels or in some cases rest upon the rock ridges, the surface deposits having been removed. This is the case on the summit of the ridges south of Sand Point and also on the height of land north of Kinburn. Similar conditions are seen on the crest of the ridge in the south part of Huntley township north of Almonte.

Drift blocks.

In places, as along the crest of the Brudenell ridge south of Clear lake, the surface is thickly strewn with large blocks of Black River limestone which now rest upon the crystalline rocks of the mountain range at an elevation of about 600 feet above the limestone deposit which is found in the flat area west of the lake itself. They have probably been derived from this outlier or from the larger area of these rocks which occurs just south of the Bonnechère at Eganville.

The large and prominent ridges of boulders, derived from the crystalline rocks north of the Ottawa, which are so frequent in the area between the lower Ottawa and the St. Lawrence rivers are rarely seen in this portion of the district.

It will be seen that one of the principal ice movements was to the south-east, following the direction of the lower part of the Ottawa river. Going southward however, the prevailing direction is to the south west, following the course of the St. Lawrence river. There is moreover a marked tendency, as the western portion of the area is reached, to assume a more westerly direction, and in some of the striæ the course is nearly west. The peculiarity of these changes in direction will be readily seen by reference to the appended list. Further west in rear of Napanee the direction of some of the ice markings is slightly to the north of west. This aspect of the question is more fully considered in the reports by Dr. R. Chalmers, who has carefully examined a large part of this area.

LIST OF STRIÆ.

List of striæ

At quarry 2 miles south of Sand Point	S. 40 E.
Road Eganville to Clear lake, near brook midway	S. 35 W.
Road west of Clear lake, Sebastopol township	S. 28 W.
Opeongo road east of Clear lake, near Constance creek	S. 25 W.
Opeongo road west from Vanbrugh post-office	S. 15 W.
Road from Opeongo road to Hyland lake	S. 30 W.
Road from Opeongo road to Eganville, east end of Lake Clear	S. 10 W.
Road 2 miles S.W. of Franktown, Beckwith township	S. 45 W.
Road 3 miles north of Franktown	S. 25 W.
Road Blacks corner to Ashton, at Jock river	S. 10 E.
Lots 15 and 16, range XI and XII, Ramsay	S. 25 E.
Road Pakenham to Snedden at railway crossing	S. 10 E.
Half mile west of Panmure corner	S. 60 E.
Half mile south of Perth	S. 28 E.
Two miles south of Perth	S. 28 E. and S. 32 E.
West of Bathurst sta. C.P.R	South, and later S.W.
Three miles north of Smiths Falls	S. 1 W. and S. 3 W.
South of Smiths Falls	S. 4 E., S. 1 W. and S. 6 W.
One mile north of Smiths Falls	S. 46 W.
Half mile south of Perth	S. 87 W. and S. 52 W.
Four miles S.W. of Perth	S. 42 W.
Two miles south of Perth	S. 47 W.
Near Beckwith lake, south of Carleton Junction	S.W.
Maberly to Sharbot lake	S. 50 W.
Boss of limestone at Sharbot lake	S. 55 to S. 45 to S. 35 W.
Road from lake to Zealand post-office	S. 35 W., S. 45 W.
Half mile north of Olivers ferry	S. 25 W.
Road from Olivers ferry to Perth, half mile from Perth	S. 40 W.
First side road south of Olivers ferry	S. 20 W.

Same road, one mile further on	S. 25 W.
One mile N.E. of Port Elmsley	S. 10 W.
Near road between Drummond and Elmsley	S. 40 W. and S. 25 W.
Two miles east of Port Elmsley	S. 5 W.
North Elmsley	S. 20 W.
Road north of Perth	S. 40 W.
Road south of Lanark	S. 35 W.
North of Middleville, near Clyde river crossing	S. 5 E.
Crossing of Tay canal, Elmsley	S. 35 W. and S. 40 W.
North of Smiths Falls	South.
Gravel ridge near Welsh's siding 3 miles north	S. 30 W.
One mile N.E. of Smiths Falls, Montague	South.
Concessions I, and A. Montague	S. 10 E.
Road one mile north of Harper post-office	S. 35 W.
Glen Tay or crossing of Tay river	S. 40 W.
Road north of Scotch line near Tay river	S. 50 W.
Same road south of Bathurst sta. C.P.R.	S. 48 W. and S. 65 W.
Scotch line road west of Perth	S. 40 W.
Half mile N.E. of Perth	S. 50 W.
Road north of Lanark	South and S. 20 W.
Near Armstrong corner Lanark	S. 50 W.
Road south of Fall brook	S. 30 W.
One mile north-west of Maberly post-office	S. 85 E.
Road crossing Bolton creek, 5 miles west of Fall brook	S. 50 W.
Road east of Middleville, Lanark	S. 10 E.
East side Robertsons lake, Lavant	S. 20 E.
South line of Darling, N. of Galbraith post-office	South.
Road half mile N.W. of Dalhousie lake	S. 45 W.
Road one mile west of McDonald's corner	S. 60 W.
Kames on road Fall brook to McDonalds corner	N. 60 E.
Near Bathurst sta. C.P.R., range IV and V, Bathurst	S. 45 W.
Near Dalhousie lake road between VIII and IX	S. 45 W.
West of McDonalds corner, lot 9, ranges X and XI	S. 50 W.
Lot 17, range I, Bathurst	S. 50 W.
Bend of road south of Tay river to Scotch road	S. 50 W.
Road between lots 20 and 21, Bathurst 1 mile east	S. 10 W.
Quarter mile S.E. of corners on road to Playfair	S. 20 W.
Half mile north of Watsons corner	S. 10 W.
Near Elliot post-office, east of Christie lake	S. 40 W.
Road from Clayton to Lanark, east line of Lanark	S. 10 W.
Forks of road one mile west of Poland	S. 10 W.
Corner of road south of Joes lake	S. 10 E.
Kingston and Pembroke railway near Folger station	S. 25 W.
South side Madawaska river on MacNab line	S. 25 E.
Road south side Calabogie lake	S. 25 E.
Road near Ashdod station, Kingston and Pembroke railway	S. 40 E.
Corner of road between Renfrew and Opeongo stations	S. 47 E.
Road S.E. of Douglas station, Canada Atlantic railway	S. 25 E.
East side Loon lake, Effingham	S. 20 W.
Road past Mazinaw lake to Cloyne	S. 10 W.
Road near Beech corner four miles west of Plevna	S. 5 W.
Addington road near Burnt bridge, Madawaska river	South.
Back road south of White lake, Darling township	S. 30 E.
Road south of Pakenham, near Indian river	S. 5 W.

Panmure corner, Huntley	S. 50 E.
South of Panmure, near Ramsay line	S. 50 E.
Half mile north of Pakenham, on road to Kinburn................	S. 30 E.
Three-fourths mile east of Antrim corner.......................	S. 60 E.
South Huntley, north of big fault	S. 50 E.
Cross roads, two miles north of Kinburn.....	S. 55 E.
One mile north-west of Hazeldean.....	S. 20 E.
100 yards west of South March station, Canada Atlantic railway.	S. 30 E.
Corner of road one mile south of Cloyne.........	S. 5 W.
Road S.E. of Carleton Place, line VIII. and IX......	Marine shells
Corner of Huntley, Goulbourne, Ramsay township.........	Marine shells
Carp station in gravel ridge..............................	Marine shells
Ridge one mile south of Sand Point.............	Marine shells
Ridge four miles north of Kinburn station..................	Marine shells
Ridge south part of Huntley township, road to Almonte ...	Marine shells

APPENDIX

Preliminary lists of fossil organic remains from the Potsdam, Beekmantown (Calciferous), Chazy, Black River, Trenton, Utica, and Pleistocene formations comprised within the Perth Sheet (No. 119) in Eastern Ontario.

BY

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INTRODUCTION.

The sedimentary formations comprised within the area of the Perth Sheet (No. 119) have afforded quite a series of fossil organic remains wherever they crop out in those portions of the counties of Carleton, Lanark and Renfrew where collections have been made from time to time by officers of the Geological Survey of Canada, as well as by local geologists and persons interested in the development of the geological resources of this portion of the Ottawa valley.

The palæontological evidence obtained in these collections indicates the presence of at least six palæozoic formations. They include the following:—

The Utica formation
The Trenton formation
The Bird's eye and Black River formation
The Chazy formation
The Beekmantown (Calciferous) formation
The Potsdam formation.

Although the Potsdam formation is referred to the Cambrian system in New York State, nevertheless the palæozoic formations of sedimentary origin comprised within the Perth Sheet all appear to belong to the one system, namely, the Ordovician or Cambro-Silurian system as it is sometimes styled, forming a very continuous and unbroken series of strata from the base of the Potsdam sandstone, as exposed within the area in question, to the bituminous shales of the Utica formation.

From the collections examined by myself as well as from the lists prepared by the late E. Billings—palæontologist to the Geological Survey in the early days of the department when the first examination and reports were made on the geological resources of this part of Canada, no evidence of truly typical Cambrian strata has been recorded. The presence of othocerata and gasteropoda in the sandstones of the Potsdam formation clearly indicate that the fauna present is not "primordial," but one appertaining to the later and subsequent series, sometimes styled "the second fauna", the Ordovician Age.

With the exception of the two collections from the Clear Lake outlier in the Township of Sebastopool, County of Renfrew, obtained in 1895 and 1896 respectively by Dr. Ells and his assistants, there are practically no systematic palæontological collections available in the department from which to prepare a satisfactory report on the fauna entombed in the sedimentary strata within the sheet in question. There are however quite a number of smaller collections which have served to identify the geological horizon in various localities. The lists are here given in the natural order of sequence and time from the oldest Potsdam to the most recent Pleistocene formations met with.

ORDOVICIAN SYSTEM.

POTSDAM FORMATION.

I. Perth, Ontario. Collected by Sir W. E. Logan and Dr. James Wilson.

In the neighbourhood of Perth, the formation consists of white sandstone displaying tracks or trails of marine organisms referred to Protichnites and Climactichnites. Two forms have been noticed on the slabs of sandstone as follows:—

1. *Protichnites. sp.* a form allied to *P*, septem-notatus, Owen.
2. *Climactichnites Wilsoni*, Logan.

The type specimen from which Sir Wm. Logan described the so-called ladder-tracks referred to as *Climactichnites* is now preserved in the Museum of the Geological Survey and exhibited on the west wall of the palæontological hall. An excellent woodcut or illustration of *Climactichnites Wilsoni*, Logan may be seen on page 107, Chapter VI of the "Geology of Canada" 1863.

It was in a quarry and on the property of Mr. Glen, lot 6, Range III, in the Township of Drummond, near the town of Perth, Ont., that the late Dr. James Wilson discovered these trails and tracks of marine organisms.

II. Lot 22, Range IX. Township of Bastard, North of Beverly, Ont.

The following species are recorded by E. Billings from the sandstones of this formation there exposed.*

Although they are not numerous, nevertheless, these forms serve well to ascertain the geological horizon to which the strata holding them belong

1. *Fucoids.*
2. *Scolithus Canadensis*, Billings.
3. *Lingula acuminata*, now known as Lingulepis acuminatus, Conrad.

III. Perth, Ontario.

1. *Scolithus Morrisi*, Dawson.§

In 1898 Mr. E. D. Ingall, of the Mines Branch of the Geological Survey Department brought to the museum of the office a fine example of the species figured by Sir Wm. Dawson in the Quarterly Journal of the Geological Society of London.† Vol. 46, p. 603.

This specimen was presented to the survey by R. J. Drummond Esq. of Perth and was obtained by him from the sandstone quarry from which the blocks were used for canal purposes.

POTSDAM-BEEKMANTOWN.

(*Passage Beds*)

IV. Smiths Falls, Ont.

During the excavations for the aqueduct along the streets of Smith's Falls, in 190I, brownish-yellow and white more or less saccharoidal sandstone layers were blasted and among the fossil remains collected by the writer were the following:—

1. *Fucoids.*
2. *Ophileta complanata*, Vanuxem (several specimens).

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* Geol. of Can., 1863, page 93.

† Quart. Journ. Geol. Soc. Vol. xlvi, pp. 515-617, fig. 7. London.

§ A fine example of this species of Scolithus from Perth, exhibited in the cases of the Geological Department in the Peter Redpath Museum of McGill University, Montreal, bears the designation. *Scolithus Morrisi*, Dawson.

The strata holding these may fairly be described as passage beds between the Potsdam formation and the next overlying series: the Beekmantown formations. The thin-bedded and arenaceous character of the strata in which the fossil remains are obtained, indicate that the littoral or shallow—water and sandstone—depositing conditions of the Potsdam had not disappeared whilst the organisms themselves are characteristic of the dolomites or calciferous sandstone of the Beekmantown formation.

CHAZY FORMATION.

V. Township of Huntley, Ont.

(*a*) In yellowish-white sandstone in the lower part with a gray limestone above, in which there is an interstratified bed of blackish-brown limestone crowded with bivalve Entomostraca not far above which are several feet of yellowish-gray, buff-weathering argillaceous magnesian limestone applicable for the purpose of hydraulic cement, the following species occur: *.

1. *Strophemena alternata*, Conrad.
2. *Rhynchonella plena*, Hall.
3. *Leperditia Canadensis*, Jones.
4. *Bathyurus Angelini*, Billings.

The *Kynchonella plena*, so characteristic of the Upper Chazy is stated to be very rare. It is now referable to the genus *Camarotœchia*.

(*b*) On lot 6, Range X. township of Huntley near Pakenham, the following species of ostracod occurs in a brownish-black limestone in great abundance.

1. *Leperditia Canadensis*, Jones.

BLACK RIVER FORMATION.

VI. Pakenham, Ontario, near Dicksons Mills.

1. *Columnaria Halli*, Nicholson.
2. *Orthoceras fusiforme*, Hall·
3. *Actinoceras Bigsbyi*, Stokes.

Of the fossil evidence obtained here, Mr. Billings writes:—

"The Birdseye and Black River formation yields very large masses of Columnaria alveolata and some of its beds abound with great orthoceratites, the chambers of which have occasionally been found by Mr. Dickson to hold large quantities of petroleum"......" Among the orthoceratites at Dicksons Mills *Orthoceras Bigsbyi* ranges from nine to eighteen inches in length, and *O. fusiforme* is met with two feet long."

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* Geol. of Can. 1863. p. 128.

† Geol. of Can. 1863, p. 173.

VII. Pakenham, Ontario. Collection of the late Sheriff Dickson.

1. *Bythotrephis* (*Chondrites*) *succulens*, Hall.
2. *Stromatocerium rugosum*, Hall.
3. *Tetradium fibratum*, Safford.
4. *Columnaria Halli*, Nicholson.
5. *Orthis tricenaria*, Conrad.
6. *Actinoceras Bigsbyi*, Stokes.

VIII. Township of McNab. Collection received from A. M. Campbell, Esq. December 10, 1890.

1. *Streptelasma profundum*, Hall.
2. *Columnaria Halli*, Nicholson.
3. *Murchisonia* (*Hormotoma*) *gracilis*, Hall.
4. *Murchisonia* (*Lophospira*) *Milleri*, Hall.
   (= *M. bicincta*, Hall of former reports.)
5. *Murchisonia* or *Loxonemao sp.*
6. *Trochonema umbilicatum*, Hall.

TRENTON FORMATION.

IX- Pakenham, Ontario, from the collection of the late Sheriff Dickson, 1890.

1. *Licrophycus minor*, Billings-
2. *Solenopora compacta*, Billings.
3. *Prasopora oculata*, Foord.
4. *Prasopora lycoperdon*, Vanuxem. (=*P. Selwyni*, Nich.)
5. *Agelacrinites Dicksoni*, Billings.
6. *Glyptocrinus ramulosus*, Billings.
7. *Pleurocystites squamosus*, Billings.
8, *Lingula quadrata*, Eichwald, as of Billings.
9. *Lingula riciniformis*, Hall.
10. *Plectambonites sericeus*. Sowerby.
11. *Rafinesquina alternata* (Conrad), Emmons.
12. *Rafinesquina deltoidea*, Conrad.
13. *Dalmanella testudinaria*, Dalman.
14. *Murchisonia bellicincta*, Hall.

15. *Fusispira subfusiformis?* Hall.
16. *Orthoceras sp.*
17. *Endoceras proliforme*, Hall.
18. *Asaphus platycephalus*, Stokes.
19. *Calymene senaria*, Conrad.
20. *Ceraurus pleurexanthemus*, Green.

X, Locality :—"One mile north of Hotel, Almonte, Ont." Collector and date :—T. C. Weston, 1866.

Horizon :—Near the summit of the Trenton formation, so far as the association of forms in the small collection examined appears to indicate.

List of species.

Bryozoa,

1. *Pachydictya acuta*, Hall.

Brachiopoda.

2. *Leptaena (Plectambonites) sericea*, Sowerby.
3. *Orthis (Dalmanella) testudinaria*, Dalman.
4. *Zygospira modesta*, Hall.

Cephalopodia.

5. *Orthoceras strigatum*, Hall.

Trilobita.

6. *Proëtus parviusculus*, Hall, or a very closely related form.
7. Portion of the cephalic shield and *pygidium* of an asaphoid or proëtid trilobite, too imperfectly preserved for identification. The larger fragment of the pygidium present in the collection resembles somewhat the flattened pygidium of *Bathyurus extans*, Hall, of Black River age, whilst it presents also affinities to *Ptychopyge*. Until better specimens are procured, it will be impossible to state definitely what the species is that is here represented.

Ostracoda.

8. *Primitia*, sp. nov., a rather large and apparently undescribed form from the Ordovician of the Ottawa valley

UTICA FORMATION.

XI. Clear Lake outlier, Clear lake, south-western corner of Renfrew county, Ontario.

Collected by R. W. Ells and L. M. Lambe, 1896. Horizon,—Lower Utica.

List of species.

Graptolitoidea.

1. *Orthograptus quadrimucronatus*, Hall.

Echinodermata.

2. *Crinoidal fragments.*

Brachiopoda.

3. *Leptobolus insignis*, Hall.
4. *Leptobolus*, sp. indt.
5. *Lingula Progne*, Billings.
6. *Lingula curta*, Hall.
7. *? Schizocrania filosa*, Hall.
8. *Plectambonites sericeus*, Sowerby. Three varieties such as are also found in the lower Utica of Gloucester and Ottawa.
9. *Orthis (Dalmanella) testudinaria*, Dalman. A rather small and depauperated variety.
10. *Zygospria modesta*. Say.

Gasterpoda.

11. *Pleurotomaria* or *Murchisonia*, sp. Too imperfectly preserved for identification.

Lamellibranchiata.

12. *Lyrodesma pulchellum*, Hall.
13. *Modiolopsis curta*, Hall.
14. *Nuculites*, sp.
15. *? Pterinea*, sp. indt.

Cephalopoda.

16. *Endoceras proteiforme*, Hall. Embryo sheaths.
17. *Orthoceras lamellosum*, Hall.
18. *Trocholites ammonius*, Emmons.

Pteropoda.

19. *Conularia gracilis*, Hall.

Trilobita.

20. *Triarthrus Becki*, Green.
21. *Asaphus latimarginatus*, Hall. (= *Asaphus Canadensis*, Chapman).

Ostracoda.

22. *Primitia Ulrichi*, Jones.

Cirripedia.

23. *Turrilepas Canadensis*, Woodward.

Note on the fauna.

The assemblage of species noted above and identified from the collection before me, represents that of the lower half of the Utica formation. It corresponds to the fauna of the same horizon found along the Rideau river below Sparks rapids and above Cummings Bridge. Among the more interesting forms discovered were :— *

Turrilepas Canadensis, Woodward. This small cirripede was first found by the writer in the impure bituminous limestone band at the head of Sparks rapids on the Rideau river, which also marks the zone of *Schizambon Canadensis*, that pretty little brachiopod formerly referred to as *Siphonotreta Scotia*, Davidson.

Conularia gracilis, Hall. A number of examples or fragments of this species appears in this collection, as indeed they do in almost every collection from this formation, from the Manitoulin islands, Lake Huron, from Ontario and Quebec, even as far north as the Lake St. John, outlier, where well-preserved examples of this interesting sessile *Conularia* were obtained by the late Dr. A. R. C. Selwyn in 1870.

For further information on this species the reader is referred to that most interesting paper by Dr. R. Ruedemann entitled :—The "Discovery of a Sessile Conularia.†

XII. Fossils from Clear lake, Township of Sebastopool, County of Renfrew, Ont. collected by W. J. Wilson, 1895, for Dr. R. W. Ells.

1. *Clinacograptus*, sp.
2. *Crinoidal fragments.*
3. *Lingula Progne*, Billings.
4. *Lingula curta* ? Hall.
5. *Leptobolus insignis*, Hall.
6. *Leptobolus* sp.
7. *Plectambonites sericeus*, Sowerby.
8. *Orthis* (*Dalmanella*) *testudinaria*, Dalman.
9. *Zygospira modesta*, Say.

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* Geological Magazine, Dec. III. Vol. VI, no. 300, p. 271, 1889.

† Amer. Geol., Vol. 17. No. 3, pp. 158-165. March 1896. Minneapolis, Minn.

10. *Trocholites ammonius*, Emmons.
11. *Endoceras proteiforme* (?) Hall.
12 *Conularia gracilis*, Hall.
13. *Tiarthrus Becki*. Green, adult and lawal forms.
14. *Asaphus latimarginatus*, Hall (= *Asaphus Canadensis*, Chapman).
15. *Primitia Ulrichi*, Jones.

It was from this collection by Mr. Wilson, that the Utica formation was recorded so far west of Ottawa city, along the Ottawa valley.

SAXICAVA SAND.

XIII. Carp, Ont. Collected by H. M. Ami and W. J. Wilson, September, 26th, 1896.

In the sands and gravels overlying the clays of the valley of the Mississippi river, forming the ballast pit near the Railway Station at Carp, the following species of marine shells were found* :—

1. *Saxicava rugosa*, Linnæus.
2. *Macoma Balthica, L.* (= M. fragilis, Fabricius of previous lists.)
3. *Balanus Hameri*, Ascanius.
4. *Balanus crenatus*, Bruguière.

Immediately south of the Canada Atlantic and Parry Sound Railway Station at Carp, the hill, some twenty five feet in height, consisting of coarse gravel, admirably suited for ballast and made up for the most part of well-worn, and rounded sea-washed pebbles of Archæan age, was utilised by the railway authorities, and practically carried away in its entirety.

Collected by by W. J. Wilson & H.M.Ami, Sept. 26th, 1896.

XIV. Mohrs corners P.O. Collected by W. J. Wilson and H. M. Ami, September, 26th, 1896.

On the brow of the hill, and three-quarters of a mile to the south-east of Galetta Station along the Canada Atlantic and Parry Sound Railway, forming a sand and clay terrace, the following marine shells were found by Mr. W. J. Wilson and the writer, and recorded in the October number of the Ottawa Naturalist for 1896.*

1. *Saxicava rugosa*, L.
2. *Macoma Balthica*, L.

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* The Ottawa Naturalist, Vol. x,, No. 7, p. 142, Oct. 1896.

QUATERNARY SYSTEM.

PLEISTOCENE.

(Shell-Marl or lacustrine deposit)

XV. Lake Clear, Township of Sebastopool, Renfrew Co., Ontario.

In Report of Progress of the Geological Survey of Canada for 1857, Mr. E. Billings, who visited the locality, states that in the smaller lakes north of and connected with Lake Clear he "found that extensive deposits of shell-marl were in the progress of accumulation."

From these deposits he found the following species :—

1. *Physa heterostropha*, Say.
2. *Planorbis campanulatus*, Say.
3. *Planorbis bicarinatus*, Rackett.
4. *Paludina decisa*, Say.
5. *Cyclas orbicularis*, Say.
6. *Unio complanatus*, Lea.
7. *Anodon fluviatilis*, Lea.

Mr. Billings adds the following interesting note :—"The marl however consists almost altogether of the shells of the species of Gasteropoda above mentioned and as the living specimens do not appear to be more numerous in the lake than they are upon the shores of some of the rivers of the country, it must have required a great length of time for these remains to accumulate to the depth of several feet, which is often attained by the beds of marl."

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* Ottawa Naturalist, Vol. X, No. 7, p. 143, 1896.

GEOLOGICAL SURVEY OF CANADA

ROBERT BELL, M.D., D.Sc. (CANTAB.), LL.D., F.R.S., I.S.O.

REPORT

ON

THE PICTOU COAL FIELD

NOVA SCOTIA

BY

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(With a map.)

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PREFACE.

This report has been written to accompany a lately revised map of the Pictou Coal Field and its neighborhood. It has been prepared more especially for the use of local observers and will be found to dwell on some details which otherwise would not be of sufficient importance to receive notice.

The district described offers within a small radius a wide field for observation and it is one convenient of access from either Stellarton or New Glasgow as a centre. It supplies representative series of several geological systems, many exposures of varied structure, and also what is of importance to the student, its examination will suggest questions which he may put to himself and find no answer anticipated. It also leaves opportunity for detecting overlooked details, and for modifying present deductions, and so makes the field one of increased interest. Reference also is made to the diverse views held respecting the correlation of some rock-series in order to call local attention to the discussions and thus stimulate exploration and impartial criticism.

It is assumed that the student of the structure of the field has access to the principal reports and papers herein referred to, especially to the report of Sir W. E. Logan of 1866-9.

LITERATURE, IN PART, OF THE PICTOU COAL FIELD.

Haliburton's History; 1829, p. 414.
Jackson & Alger, with map, 1832.
Gesner's Geology with map, 1836.
Gesner's Industrial Resources 1849, p. 229.
Journals of the House of Assembly 1845, App. 49.
Dawson's Acadian Geology, 1855 and later editions.
The Coal Fields of Nova Scotia, 1871; J. Rutherford.
Geol. Surv. Report, 1866-69; Logan & Hartley.
Geol. Surv. Reports part P., 1886 and 1892, with maps, and 1902-3, by H. Fletcher.
The Pictou Coal Field, 1893; N.S. Inst. Sc.; H. S. Poole.
History of Pictou County, Dr. Paterson, Trans. N.S. Mining Society, 1894, Vol. II, 2.
Inspector of Mines Reports, 1860, etc.
Quart. Jour. Geol. Soc. Vol. 1, p. 322, of 1845, etc.
Trans. N.S. Inst. of Sc.; Sundry papers by R. G. Haliburton, 1867.
Henry Poole, 1863, etc.; H. S. Poole; E. Gilpin; Dr. Honneyman.
Canadian Naturalist, Aug. 1860, H. Poole.
Dr. Honneyman's papers; *See* Geol. Surv. Report, part P. 1886.
Trans. N.S. Mining Soc.;—Can. Mining Inst.—Am. Inst. of M. E., and other kindred publications.

References.—Where in the text a name and page only are given they refer to the above papers specially relating to this coal field; *e. g.* Logan and Hartley:—These names refer to the Geological Survey Rep. of 1866-69.

THE COAL FIELD OF PICTOU COUNTY, NOVA SCOTIA.

Map :—The regular map of the province of Nova Scotia issued in sheets by the Geological Survey is on a scale of one mile to the inch and on it the Pictou Coal Field, although of small area, is so cut up that parts of it appears on four separate sheets. This is a great inconvenience for reference to so important a district and is one which the accompanying map as a unit avoids.

Obligations of the writer acknowledged.

This map is a revision to date of that referred to by the writer in his paper of 1893, where due credit for the accuracy of the topography was given to the resurveys of the late Mr. J. G. Rutherford, and to the reductions and replottings of mining and other plans by Mr. Fletcher of the Geological Survey. In the study of this complicated field the experience and advice of Mr. Fletcher were invaluable and freely drawn upon by the writer. No attempt was made to contour the surface, but the directions of the underground levels at various depths of the pit workings are shown by dotted lines. Elevations above sea-level are noted in places along the railways and on hill tops. A glance at this map and at the faults which are marked shows that the neighborhood has been much disturbed and a study of it may leave a doubt whether the condition in some parts has been correctly represented. As time goes on and fresh exposures of the rock structure are brought to light it is probable that some modifications may be suggested. It is hence desirable that observations be kept and forwarded to The Geological Survey, Ottawa, for record.

It was explained in the paper of 1893 by the writer, on what grounds changes were then made from the report of 1866-69 in which Logan was careful to state—'What is now offered is to be considered as only a distant approximation to the truth, to be improved hereafter as occasion may serve and further developments may occur.' This proviso is extended to the present report, the structure of the field being complicated and explorations still imperfect.

Notes on the way to the field.

Location of the Field :—The geological observer travelling by rail for the Pictou Coal Field, on leaving Truro, passes through cuttings of bright-red, massive, soft, Triassic* sandstone, the highest in the geological sequence with the exception of the Pleistocene and recent deposits. Just beyond Valley, the first station, a bluff across the river marks the southern end of a flat of cultivated ground. At the northern end of this, above the sweep to the west taken by the river, horizontal beds of these sandstones rest on steeply inclined rocks of another series, dipping upstream, duller and darker in colour, harder and more angular infracture. The exposure offers a good example, easily seen, of an important structural feature—a well defined unconformable contact. The older rocks now entered on are followed by the railway for many miles. They have been brought into prominence by some palæontologists who have questioned the horizon assigned them by the field geologists of the Survey; and easily examined at the succeeding stations; they are distinguished as the rocks of Union and Riversdale. They yield a fossil fauna and flora, and the latter, thin beds of coal.†

Palæontological dispute.

Further east a sprinkling of copper pyrites in rocks of the later age near Lansdowne gave a "mine" to the Copper Crown Co., in 1899.

Continuing onward the watershed at an elevation of 560 feet is crossed and a descent made to the East river, a stream of moderate size, that, in its upper reaches appears to occupy a valley of erosion and to follow the same course it held in early Carboniferous times before the wide spread series associated with massive marine limestone and plaster were deposited. Hopewell passed, the main branches ofthe river unite at Ferrona and enter a rocky gorge cut in preglacial ages. On the edge of the ravine the track runs through a district of low hummocks and kettle holes which mark the recession southward of the pleistocene ice.

At Riverton, the ravine widens, the river strikes another series of‡ bright-coloured rocks which are shattered and imperfectly cleaved, and it is there diverted to make a great U-shaped bend. Continuing northward by the river in the dark gray rocks which form the central margin on the south side of the coal field the rocky ravine is left behind, and a well marked fault crossing the stream brings against the gray series a conglomerate of the Middle Carboniferous. Across the river to the right, McGregor hill supplies an illustration of a diorite neck surrounded by gravel set in volcanic ash.

The next turn of the stream shows at the pumping station red stained, Millstone Grit beds, and almost immediately after the train draws up at Stellarton Junction where the crop of the McGregor seam is crossed by the river. Another mile and the verdant intervale studded with fine elms is passed, tide water is reached and exposures are seen on either side of the black bituminous shales which to a depth of 1,000 feet overlie the main coal seam of this section of country.

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* The Newark system of U. S. A., geologists.

† Geol. Surv. Rep. Vol. V, (N.S.) part P., p. 18.

‡ Geol. Surv. Rep. 1869, Hartley's No. 2, Section 3.

The easily eroded measures of the coal-bearing series left behind, the river gathers its waters together and flows through a narrowed preglacial channel, cutting the hill range, chiefly composed of a thick bed of coarse conglomerate, which forms the northern margin of the coal field at New Glasgow. Here is another battle ground of geologist, a base on which rival views have been urged.*

A geological battle ground.

As shown on the map, the area of the coal field is certainly very limited in extent, but it includes all that is known of the productive measures in Pictou county. It is true that seams of coal do exist in other parts of the county, but they are all thin and nowhere of workable thickness. In many places outside this area, pits and boreholes have been since 1858 put down in search of coal, but all attempts to extend the field have been so far unsuccessful.

The structure and the relations which exist north of the New Glasgow conglomerate to the Productive Coal Measures, prospectors are slow to realize or to acknowledge. As to the hopes entertained on the one hand and the improbabilities on the other, for success attending explorations outside the field, they later on will be briefly considered.

Physical Geography.—The coal field of Pictou lies some 9 miles in land from the shore of Northumberland strait and to the south of a range of high land, at the head of the navigable tidal waters of the East river, where the town of New Glasgow is built.

Surface conditions.

The East river intersects the centre, and the west and east districts are drained by brooks tributary to the Middle and Sutherland rivers. They all have chosen faulted ground for their exits. The area occupied by the Productive Measures averages nine by three miles, and the greater part is composed of soft rocks which have been easily eroded, making the field appear to occupy a valley between hills of older rocks to the south and newer strata to the north. Faults have disturbed the stratification and tilted it. Irregularity of erosion has consequently ensued and parts of the field less easily worn away, as at Thorburn, Black Mines and Westville, have retained a greater altitude their elevation somewhat exceeding 200 feet. Portions of the hill ranges to the north and south retain still higher elevations, 350 feet to double that altitude. The present streams, for the most part flow over rocky beds, having either cut through the glacial deposits or been diverted by them. McCulloch brook, emptying into the Middle river supplies an illustration of the latter condition. Salt water is met by the main streams at the head of long arms of the sea more or less silted up and with their channels now depressed below the reach of eroding forces, making it evident that subsidence here has been the nature of the more recent movements affecting the relation of land and sea. The influence the geological structure has had on the contour of the surface is indicated by the configuration in many places; for example, the Westville district separated by a fault of 2,600 feet from the Albion district has the line of separation marked by the general course of McCulloch brook; and the dip of the strata in the former district is indicated by the direction of the small water courses leading to the brook. Then the outcropping of the base of the great conglomerate bed coincides with the general direction of the Fraser mountain range at New Glasgow, and the older and harder pre-Carboniferous rocks give a range of higher ground on the southern rim of the field.

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*See Permian System.

Subsidence of the land.

Theoretical Considerations:—To arrive at some idea of the circumstances that lead to the apparently limited area of the field, and to theorize on the possibility of an unseen extension still existing, it may be well to shortly review the chief cycles of change that the remains of systems and formations have recorded. To this part of the country the form, much as we have it today, was given in very early epochs. The limits seem to have been established, the chief lines of movement defined before the dawn of life, if that were with the Cambrian, and the directions of relief during oscillations of level, then begun, continued to act, probably for all the continental changes that have since occurred.

Growth of the continent.

The nuclear Laurentian plateau of the continent, centring round the indenting Hudson bay, has the River St. Lawrence as its southeastern border. Parallelling the river, the Appalachian mountains, under other names extend to the Gulf and entangle in their folds the successive deposits of the Palæozoic, made up of the waste of the Archæan. The older members of the series in New Brunswick present a lower front to the Gulf and form a geological bay occupied by undistubed sediments of the Middle Carboniferous; this in turn is overlaid by the Permo-carboniferous or Permian of Prince Edward island.

Along the southeast margin of the axial plateau, seemingly unbroken, the continental movements in Azoic times established lines of permanent weakness which governed the future structure of our eastern section of the province. The fracture bounding the continental shelf at the point where it is deflected 60° sharply to the east, sent westward from the embayment, a branch fault which appears to have continued to mark a line of weakness and movement for subsequent oscillations of a general character between Cape Breton and Newfoundland. It affected the northeastwardly continuation of the Appalachian disturbances and caused some of them to deflect along the Cobequid hills and again change their course through Inverness. Thus was left an area comparatively less disturbed, which is now occupied by the Gulf and the strip of shore fringing it. Within this jib-shaped area the coal measures apparently were the last deposits to be seriously affected by the orogenic movements which developed the primary faults approximately parallel with the hill ranges and the secondary fractures diagonal to them.

Lines of weakness.

Relieved by the Bay of Fundy faulting, and the folding that radiated from Shepody mountain, the Wallace anticline which passes east through it gave shelter to the Cumberland Coal Field. The protrusion of the old rocks of Mount Dalhousie and its extended base along a primary dislocation gave shelter behind Waters hill to the Pictou Coal Field, remaining within the faulting of subsequent movements. If this view be correct, the prospect of another field of coal existing away from the sheltering rim is not encouraging, unless, indeed, a similar structure can be found to be repeated clear of or under the overlying measures which have so far concealed it.

Structural Features :—The student will find within a radius of eight miles of New Glasgow many illustrations of geological phenomena: 1st, faults; 2nd, unconformities; 3rd, sections of continuous series of deposits; 4th, cleavage, induration and alteration due to igneous intrusions and lateral pressure; 5th, opportunities to note the difference in correlated series, and 6th, the difficulties of distinguishing between some series of distinct horizons.

1. *Faultings of the Field.*—Of these, there are boundary faults of a magnitude difficult to estimate; secondary faults showing displacement of stratigraphic importance; and settlement faults, merely local. These have been in part traced and mapped. Some have been cut only in working the pits, others have been safely assumed from observation of changes of dip and character of strata, but good exposures of faulting can be studied on the banks of several water courses, as for example: on Stewarts brook in the ravine near the place where it joins McLellans brook; lower down the last named brook, below the grist mill; then below at the old fulling-mill dam, and again, before the

Faults.

mouth of Marsh brook is reached there is a curiously contorted area with steep dips but probably without actual faulting. A similiar area is repeated lower down at the horse shoe sweep near Black's old mill site. (Geol. Surv. Report Vol. V, (N.S.) part P., p. 107.)

Faults that can be seen.

The Fletcher fault, one of magnitude, is to be seen exceptionally well exposed crossing McCullochs brook half a mile below the Drummond mine railway bridge; another important fault is indicated by vertical rocks on Blackwoods brook on the east side of the road in front of the New Glasgow hospital. There is the fault spoken of on the East river at the ford below the asylum. There is the McCullochs brook fault, estimated at 2,600 feet separating the Westville from the Albion coal district. A great fault crosses the Middle river 200 yards below Union centre bridge and separates Millstone Grit from rocks of the Carboniferous limestone. The importance and age of these several faultings can be seen by consulting the map.

Relative importance of certain faults.

In their assigned positions and importance, many of the small faults have been subjected to much revision since they were noted in 1869 (1): Potters brook fault has lost its prominence and direction; McLeod fault, west of the East river has disappeared; the Mill-road fault remains unproven; the Lawson fault has been found of no importance; the West fault has ceased to separate the Millstone Grit from the Coal Measures and has, at opposite ends, its position taken by members of two series of faults; those from the north, the Black Diamond series, are down-throws to the west, while those entering the coal field from the south, the Drummond series, are down-throws to the east: the McCulloch brook fault has its position altered and its assumed magnitude increased. It has been found in the Albion pit workings that all the faults, east of the English slope, are down-throws to the east, while those to the west have a drop in the opposite direction. In the Vale colliery, further workings since 1893, have disclosed that the faults met as the north fault is approached, terminate to the westward before the syncline is reached.

In a study of this field the relative age of the main faultings is of importance towards the determination of a possible extension of the area of the field. Some faults undoubtedly ceased to operate before the Permian was entered upon; others again affected the Permian as well as the Coal Measures. It is certain that the portion of the north fault east of New Glasgow belongs to the former class, while it is suspected that the north-going fault passing the shafts of the crushed mines is one of a group belonging to the latter.

(1.) Poole 1893 p. 237, refers to several of the faults of Logan, 1869; pp. 49, 85; 50, 75; 22,43,49; 33, 36; 73, 79, 81, 102; 77, 83, 85; 26, 36, 50, 73.

Contacts of formations.

2. *Unconformities* :—Between the base of the New Glasgow conglomerate and the underlying series, an unconformable contact can be well seen on Blackwells brook under the hospital; and on McCullochs brook above the iron bridge of the railway to Pictou, the conglomerate occupies two depressions in the underlying Devonian. Contacts of the same series may be got also on the left bank of the Middle river above the dam at Alma and on Browns brook flowing to it from the west.

Then there are contacts exposed on the East river at Riverton; at Park's mill falls on Sutherland's river; others fairly well shown on McLeans brook; a contact at the fault below Union Centre bridge; contacts between the mills in the pass of McLellans brook; contact of conglomerate on fossiliferous Silurian 200 yards above the grist mill on the left bank of this brook, and in the ravine up Stewart's brook. Here also are contacts with igneous rocks, and at the head of the ravine the road has a wall of diorite on the north side and rocks of Carboniferous limestone for its southern wall.

Other contacts of igneous dykes and masses are exposed on the top of Blackwoods mountain with Silurian; and at Park's mills with Cambro-silurian strata.

3. *Sections of Continuous Series of Strata* :—These can be found very generally in the streams when the water is low. The banks of the Middle river and McLeods brook show a Millstone Grit series. McLellans brook exhibits sections of the black shales, and the series overlying them of sandstones, oil shales and thin coal seams, etc. The gorge of the East river displays cuttings through Lower Carboniferous rocks. The numerous arrows engraved on the map indicate where exposures have been observed.

Systematic collection of fossils.

4. *Cleavage, etc.* :—Examples of alteration are to be met with along the hill range of pre-carboniferous rocks bounding the south margin of the field; in Cambro-silurian westward of Park's mills; in members of the Carboniferous limestone a difference in degree of alteration, may be noted on comparing those of the pass of McLellans brook with the series to the south grouped with them. The patch of brightly red-stained non-fossiliferous rocks, where the East river makes a U bend at Riverton, shows distinct cleavage in some bands, and a generally shattered condition; a contrast to the overlying gray series of the gorge of Hartley's No. 2 section, and to the Carboniferous limestone rocks up stream. The diversion of the river from the straight course of the gorge at this point is worthy of note.

Fossils.—The statement has been made that no help from fossil plants could be had in a search for extensions of the coal field. This is true of our present knowledge, but it is not however safe to say it will always be so, and the making of collections should be encouraged in order that sound generalizations may be adduced. In order to do this, it is essential that every care be exercised to record correctly the locality from which each specimen is taken, and also to note the ease with which specimens of each species are obtained, whether (*a*) numerous, (*b*) common, or (*c*) rare at each locality. The collecting of fine specimens is of minor importance.

Comparative values of fossils.

Animal remains are likely to be more valuable for determination of horizons, as the extension in time is generally much shorter in the life of animals than that of plants, and their collection should not be overlooked. Further, there may, however, have been a greater prevalence of certain species at periods represented by particular beds; periods of luxuriance and periods of degeneracy, long before extinction, hence the desirability of noting the frequency of occurrence.

Replacement of sediments.

5. *Comparison of correlated Series*:—A substitution of sandstone for black shale rapidly takes place in the beds immediately overlying the Main seam to the westward of Stellarton, and in the Colin pits, sandstone was also found occupying the horizon of black shale at the adjoining Dalhousie pits. The interposition of a bed of black fire-clay persistent in the Acadia seam throughout the Westville division of the field has no recognized equivalent in the Mainseam of the Albion division, even where workings approach within half a mile, and yet the belief is general that one is the continuation of the other. A comparison of sections taken of the Acadia seam and associated strata on the Middle river in the Black Diamond, Acadia and Drummond mines shows great variation. So also sections of the Main and other seams taken along the outcrop of the Albion division furnish examples of replacement of bituminous shales for coal, and the interposition of local beds of cannel clay ironstone and even sandstone.

6. *Distinction of Series*:—A stranger to the Carboniferous, reading of the various divisions given to the system as it occurs in this province, and hearing of the different opinions held in the past respecting the horizon at certain localities, is lost in the seeming hopelessness of ever

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Consult: Q. J. Geol. Soc. 1903, Vol. lix., page 17. By E. A. N. Arber.
2. Proc. Roy. Phy. Soc. E. 1893, vol. xii., page 183. By R. Kidston.
3. Trans. Y. Nat. Union, 1888, part 14, page 6—ibid.
4. Trans. Roy. Soc. E. 1887, vol. xxxiii., page 335.
5. Trans. Inst. M. E. 1903, vol. xxv., part 3, page 371. By Arber.

being able to distinguish between the divisions, so similar do hand specimens from some of the groups appear to be on examination. Fossil botany gives at present no help and where questions have been raised, reliance can be placed only on the stratigraphy and on the physiography of the districts. The discussion, however, has been of value in accentuating the need of caution in weighing fossil evidence without taking into account field conditions. Not only may the observer be at fault with hand specimens, but he may also be left in doubt by examination merely of small localities.

Fossil botany imperfect guide.

The neighborhood of New Glasgow supplies excellent opportunity to compare strata overlying the New Glasgow conglomerate with the sandstone and shales on which it unconformably rests, and with measures associated with coal seams on Marsh brook and beds accompanying marine limestone south of the pass on McLellan brook-strata which have respectively been assigned to the horizons of Permo-carboniferous, Millstone Grit, Coal Measures and Carboniferous Limestone.

Certain terms defined.

One may even go further in these comparisons and mark the characteristic features of this series with observations on the Union beds, in passing from Truro-beds that have been classed as Milstone Grit and even higher. In this connection, it may be well to repeat that the term Millstone Grit is used in Nova Scotia, not as implying belief in an identity of age with measures so-called in England but to define the series conformably underlying the Productive Measures of the province.

Colours of strata.

Colour, in a general way assists in the determination of horizons in this neighborhood, but caution has to be exercised when tracing selected beds or bands of rocks, as marked changes occur in colour and constituents within comparatively short distances; changes that imply local conditions of deposition, limited in area; changes that suggest a narrowness to the coal field at its inception and that the extra thickness of the seams of Pictou and their individual characteristics owe much to a shelter from the open sea to the north, given at the time of deposition by the older rocks of Waters hill. The want of similarity in the Acadia seam-thick, with black and gray measures where worked at Westville-thin, with fireclay substitutes and reddened sandstones on Middle river, misled observers for a time as to the structure of that portion of the field.

Then the lowest interbedded sandstones and shales of the New Glasgow conglomerate, made up of the waste from its basal rocks are often very red, while one of its immediately overlying sandstones is exceptional in weathering quite white, with glistening grains unencrusted by iron oxide.

Limestone agglomerate.

Characteristic in the sandstone series forming the base of the New Glasgow conglomerate are bands composed of an agglomerate of impure limestone, stained very dark, possibly by manganese. They occur at two or three places in the narrow exposure on Blackwood brook and to the eastward along the same line of strike, even past Merigonish, but they are not known in the series classed as Millstone Grit, north of Union centre bridge on the Middle river nor under the Productive Coal Mesures of the East river; while they are known in the lower Millstone Grit of the Joggins section, at Cape Meringouin and toward Cape Enragé in New Brunswick.

GEOLOGICAL SYSTEMS REPRESENTED.

Representatives of the following systems, given in ascending order, are found within the region depicted on the accompanying map:

1. Cambro-silurian.
2. Silurian.
3. Devonian.
4. Carboniferous Conglomerate } Lower Carboniferous.
5. Carboniferous Limestone. }
6. Millstone Grit.
7. Coal Measures.
8. Permian.
9. Igneous intrusions in deposits of several ages.
10. Pleistocene.

River falls.

Cambro-Silurian:—'The rocks first seen on Sutherlands river, under the Carboniferous of the Pictou Coal field, belong to this group. Greenish flinty argillites or strata mixed with dark green trap in the gorge with a succession of fine falls at Park's mills where the cliffs rise to the height of 50 feet, marking the passage of the river over the contact of the two groups of strata above the bridge. large outcrops of dark and light green traps and reddish gray hematite, flinty compact felsite, quartz felsite and red soft argillite in shaly layers are succeeded by fine, massive, jointed, reddish-gray conglomerate and grit of this age. These continue to the bridge on the St. Mary road, where they are overlaid by Medina and higher Silurian strata remarkable rich in fossils.' This description by Mr. Fletcher is from the Geological Survey Report 1886 part P., p. 33 and reference to the same locality will be found in the Trans. of the N. S. Inst. of Sc., Vol. III p. 69 and Vol. IV p. 463. Notice of other exposures in the neighborhood is given in the Geol. Survey Report 1889-91, pp. 8 and 9, while the map makes it clear where igneous intrusions among these and Silurian strata skirting the southern boundary of the coal field may easily be examined. No fossils have as yet been found in these rocks.

Prospectors mistakes.

Silurian.—Among the older rocks forming the southern rim of the coal field those of the Silurian age have exceptional interest for the prospector, as their black beds on McLellan brook have been sufficiently deceptive to induce exploration for coal. The student will find the pass of McLellan brook a very convenient locality for comparing lithologically the strata of the Coal Measures, among which workable seams do in some places occur, with beds which have some similarity of appearance and yet in which search for coal is hopeless.

True black shales of the Coal Measures are well exposed on McLellan brook below the grist mill, while at the head of the mill dam on the left bank of the stream a patch of Silurian gray shale carrying fossils is seen in contact underlying a coarse conglomérate of Carboniferous age.

Silurian strata.

Other Silurian strata, also fossiliferous, which might be at the first glance mistaken for the red beds so generally associated with the limestones of the Lower Carboniferous, can be examined on the south side of the first bridge above the dam on the south branch or Stewarts brook; and for comparison with them rocks of the Lower Carboniferous can be seen at the second bridge, a quarter of a mile higher up. A short distance further up-stream the deceptive black beds can be studied on the north side of the road. Placed side, by side the difference in the character of the black shaley fragments of the Coal Measures and the black slatey pieces of Silurian deposits will easily be apparent, while the former is generally softer with an irregularly broken edge, the latter is firmer, with more of an knife-edge fracture.

Devonian.—In beds containing plant remains, of a later age than Silurian, and therefore more likely to attract coal prospectors, the mistake has also been made of assuming that a black color in argillaceous strata indicates a possible association with coal, but the facility with which beds of Silurian age may be recognized, apart from those of the

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Trans. N.S. Instit. Sc. Vol. III, p. 69, Vol. IV, p. 463.

Geol. Lurv. Rep. 1886, part P. p. 26 Medina, p. 43 ; Upper Clinton, p. 46 - Lower Lower Hilderberg, p. 43.

Geol. Surv. Rep. 1892, part P. Medina, p. 11 ; Upper Clinton, p. 12 ; Lower Hilderberg, p. 15.

Disputed horizons.

Carboniferous, does not extend to the distinguishing of beds of Upper Devonian from Lower Carboniferous rocks. For the present, there is at least a diversity of opinion among recognized geologists and palæontologists respecting the horizons of certain series of these disputed measures in Nova Scotia, but so far as the immediate neighborhood under review is concerned there can be no doubt that the series shown on the map as Devonian at Fishpools, at East river, and at Alma on the Middle river, do not belong to the Lower Carboniferous. The controverted ground lies to the southward and westward of the coal field. Much has been written on the issue and the dispute appeared serious owing to the misconceptions of participants who had scant or no knowledge of the local stratigraphy. For those who may be disposed to look up the subject, a guide will be found in the papers of Fletcher, Ells and Ami in the Transactions of the Nova Scotia Institute of Science and the Ottawa Naturalist.

These papers may be supplemented by the suggestive discussion elsewhere in articles of Matthew, White and Whiteaves.

Fossils.

Exposures of Devonian with characteristic fossils, Psilophyton and Pinnularia, are well seen at the dam of the Alma axe factory, at the mouth of Browns brook, also east of Middle river in the banks and bed of McCullochs brook, as far as Waters hill. At these localities the unconformable contact of the New Glasgow conglomerate appears capping or occupying depressions of the Devonian within ancient ravines, which may have been produced by north and south upthrow faults to the east.

Conglomerates.

Lower Carboniferous.—Basal conglomerates, probably of this age occur at several places on the south margin of the field. On Sutherlands river below the picturesque falls at Parks mills are conglomerates which were thought might belong to the lowest series. Some of them at least do not as they contain pebbles of the Carboniferous limestone, and these must be at or near the base of the Millstone Grit. A little lower down at the junction of McLeans brook with the river a heavy conglomerate contains numerous pebbles of hematite, some even 6 inches in diameter, and this also may be of the later age since a fault has been detected, as shown, between it and the gypsum limestone series higher up the brook.

On McGregors mountain there is conglomerate in contact with Silurian and the basaltic trap. It is cemented by volcanic ash and may be of the basal series. To this series also may belong, the con-

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Annual Report, Geol. Surv. Can. Vol. II (N.S.) 1886, part P. p. 33.
Geol. Sur. Rep. 1893, pp. 17, 46, 52.

glomerate resting on Silurian rocks at the head of the grist mill dam on McLellan brook.

Along this range of hills and the country to the south there is a wide expanse of succeeding strata much shattered. These in turn are overlaid by sandstones, reddish shales and marls with greenish blotches, but the massive limestones and gypsums on the East river rest directly on Silurian strata without intermediary conglomerates. The bright red beds of shale and marl occurring here with the Carboniferous limestone are very characteristic of this series all along the hill region of eastern America, southward into Virginia.

Succession conformable.

Millstone Grit.—The rocks of this age succeed unconformable the Carboniferous limestone series, and immediately underlie, without a distinct separation those which are classed as the productive Coal Measures. They have yielded as yet no coal seam of value. On the Geological map of 1866-9 there is a demarcation by faulting which later re-examination has failed to confirm. Here, as in Cumberland and Cape Breton counties, no unconformity has been detected separating these two series of rocks and the line selected is consequently an arbitrary one, chosen largely for convenience. As there has been some late criticism on the use of the above terms, adopted from the nomenclature of Great Britain, it may be instructive to mention that they are used in Nova Scotia to mark relative positions on stratigraphic ground, regardless as to whether the strata are homotaxial or not with those of Europe. As a further guard against a growing misconception, it seems also well to mention that the term "Productive" does not embrace all strata in which seams of coal may be found; the matter of thickness of deposits and quality of coal seams are entirely outside that of horizon and are determined by local conditions.*

Changes from the map of 1869.

A comparison of the map of 1869 with the current issue shows some changes of view have occurred since the first map was issued and for these, explanations may be found in Mr. Fletcher's Report of the Geol. Survey for 1890-91, Vol. V, part P., p. 102; and in the Trans. N. S. Inst. Sc., Vol. I, Ser. 2, p. 261-272, by the writer.†

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* Coal seams of workable size and quality are not confined to the Carboniferous measures. In parts of Europe the Tertiary yields lignite; in the North-west Territories and British Columbia excellent coal is got in Cretaceous strata; the Newark beds of the eastern seaboard contain workable seams and valuable beds are mined in the Millstone Grit of Great Britain.

†Annual Report Geol. Surv., Vol. V, (N.S.) 1890-91, pp. 74-86.

Geol. Surv. Rep. 1866-9, pp. 70, 76.

Acad. Geol., p. 285: Sup. p. 51.

Trans. N. S. Inst. Sc. Honneyman, Vol. V., p. 213; Gilpin, Vol. IV, p. 138.

Strata here distinguished as Millstone Grit may be separated into two groups: first, those directly and in place underlying Coal Measures; and secondly, the mass of rocks east of New Glasgow and separated by faults from the eastern end of the coal basin.

Two groups.

Of the relative horizon of the former, there can be no doubt; they are in series below the Coal Measures on the East and Middle rivers, and are in part described in Hartley's number 1 section on McLeods brook, p. 60. The full section on the Middle river has yet to be measured. They are to be distinguished from the second group, the mass of Pine tree, by an entire absence of calcareous beds; they are also generally brighter in colour, although both are more or less stained by iron oxide; the discoloration of the later, though not uniform, is greater and brighter in some of its lower members and less so in the upper beds. The second, while isolated by faults to the south, is found near New Glasgow in unconformable contact with the basal conglomerate of the Permian and it contains the beds of calcareous agglomerate stained by iron or manganese oxide, described by Logan on p. 9 of his report as black bastard limestone.

Quality of coals not uniform.

Coal Measures.—Workable seams so far discovered in this field have been wholly confined to strata classed as Productive Coal Measures. Coal seams found at other horizons are always inferior; generally they are coarse and thin, include layers of stone, or are irregular in thickness, and in faulty ground are limited in extent. In fact, much of the Coal Measures proper, is barren and disappointing; or what is even worse, when a seam is found it may have some of the weaknesses of the other strata, or fail to be persistent over much territory. To the honest prospector and adventurer the experience gained by the operator in this field is instructive, for the hope of the sanguine explorer is often based on the common belief that coal seams have a habit of improving with depth from the surface. While this is true regarding the very outcropping within the range of drainage and weathering, it stops there and ultimate success depends entirely on the starting points of the explorations, e.g., the Acadia seam, thick and excellent at Westville, is split up and unworkable at the Middle river, and on Browns brook is represented only by some black shale along the crop. On the dip along the Black Diamond planeways, it is good above, but deteriorated and finally unworkable in depth. The crop of the Albion main seam, at Dalhousie is 38 feet in thickness, nearly all good coal, but much of it becomes coarse at the intervale, and at the Pictou pit across the river, black shales replace all but 18 inches of coal. To the "deep" on the seam, the Dalhousie pit north levels met with inferior gray coal.

Money wasted by prospectors.

Further illustrations of deterioration in depth could be cited, and other reasons assigned for districts of good and bad coal occurring in the same seam. The student might consider what was the area of the original deposit and the probable relation of the shores and drainage of the period. Few realize how large in the aggregate have been the sums frittered away by enthusiastic searchers for coal in unlikely places, and how small have been the chances of accidentally discovering valuable deposits much outside the limits of the field assumed by the officers of the Geological Survey.

SECTION

Of the Productive Coal Measures.

An almost continuous section of the coal measures may be obtained on McLellans brook, and some duplications of the same horizons, but showing variations in the thickness of the strata and nature of the deposits, in other portions of the field.

Marsh pit section.

The sinking of the Marsh pit, 248 feet deep, cut the highest known beds, details of which are given by Logan on page 17 of his 66-69 report, and the following is an abstract, in descending order :

DIVISION A.

	Ft. In.	Ft. In.
Strata unknown	148·00	......
Dark gray clayey shale and fireclay	52·00	......
Coal—Captain seam	......	3·00
Fireclay and shale with 4 feet of sandstone	21·1	......
Coal—inferior	....	1·8
Gray shale, etc	10·10	......
Coal	......	0·3
Gray shale, 13·3; sandstone, 43; shale, 8	64·5	......
Coal—Millrace seam	......	3·1
Fireclay, 18; sandstone, 34; shale 12	63·6	......
Coal—Geo. McKay seam	......	3·9
	349·10	19·9

Marsh brook.

Logan's section, Division B, gives the measurements of succeeding strata seen down Marsh brook. This was duplicated by a borehole, from the bottom of the McLeod pit, on the Geo. McKay seam, 1900 feet west of Marsh pit. It is here given in abstract, but it was shown in detail in the paper on the Pictou Coal Field, page 323, Trans. N.S. Instit. Sc., Vol. X, 1893.

McLeod pit section.

The borehole record, it will be seen, agrees fairly well with the brook measurements of Logan half a mile away. It is as follows :—

		Feet.
Gray fireclay		3·0
Gray arenaceous beds		29·6
Dark shales		8·6
Gray sandstones		19·0
Shales		24·0
Black shales		2·0
Soft fireclay		1·0
Sandstone		26·0
Shales and sandy shales with black calcareous partings full of shells and fish remains		50·0
Gray calcareous shales		14·4
Black shale		1·0
Fireclay		2·6
Clayey sandstone 6′ shales 13′		19·0
" 7′ " 2′		9·2
" 9′ " 4′		12·8
Coal 10 inches seam	.....	0 8
Fireclay	3·8	.....
Shales chiefly sandy, with coal streaks and veins of calcite	58·7	.....
Gray shale	8·0	.....
Black oil shale with fish remains	......	9·6
Fireclay	10·6	......
Shales	22·0	......
Black oil shale with plants	......	12·0
Fireclay	1·0	......
Shales with ironstone	59·7	.....
Shales, some black with fish remains	64·5	.....
Gray shales	19·0	. .
Sandstone 2 feet, shale with ironstone 6 feet	8·2	.....
Black shales	3·0	......
Shales, gray, 3½ feet, black with plants 20 feet	33·6	......
Shales some black, brown streak, containing plants and fish	63·4	......
Oil shale, black compact with fish remains (the cannel band of Logan)	......	6·10
Shale 2 feet, sandstone 4 feet, shale 2 feet	8·0	......
Sandstone, hard white and quarry stone	30·0	......
Shale, coal 1 inch, plants shells and fish remains.	56·8	0·1
Sandstone	68·4	......
Dark fossiliferous shale ; oil shale, black and compact, a 4 feet 3 inches band	20·6	......
Blue shale with fossils	20·0	......
Black oil shale with brawn streak	10·0	....
Fossiliferous shale, some black	27·1	......
Sandstone, and sandy shale	15·0	......
Purplish shale with nodules and red marks	16·6	......
Rusty sandstone	9:1	......
Dark shales with fossils	43·3	......

	Feet.	Feet.
Coal	......	0·6
Shales	30·7	......
Coal, Widow Chisholm seam	.....	0·5
Total of Division B to this point	1236·0	......

Borehole No. 3 of 1878, gave the following additions below the Widow Chisholm seam.

Shale 16 feet, sandstone 84 feet 2 inches, shale 3 feet 2 inches, 103 ft. 4 in.		
Coal	......	1·0
Fireclay	0 1	......

Shale brook section.

This portion is well seen in McLellans brook, Logan p. 19, and the sandstone bed has been quarried on the brook and on the Vale railway where the outcrop is deflected westwardly. The next most prominent feature to underlie the sandstone is a compact band of black shale at the mouth of Shale brook. It is one of the several thick cannel like seams which give a brown streak and yield oil on being distilled. The following is the section at Shale brook:

	Feet.	Feet.
Yellowish drab sandstone	20·0	......
Black shales with ironstone balls and fireclay	20·0	......
Here at Shale brook, compact cannel breaking into cuboidal blocks	......	5·0
Purplish sandstone (6 feet shales and fireclay)	52·0	......
Yellowish sandstones	89·0	......
Shales with a black compact band	7·0	4·6
Yellowish sandstones with a 2 inches band of clay-ironstone	163·0	......
Compact black cannel-like bed	......	29·0
Underclay and coal	3·0	0·3
Yellowish sandstone	50·0	......
Gray shale with upright plants	5·3	......
Sandstone, some shaley and flaggy	77·0	......

Black's mill site.

This division B of Logan terminates at Black's old mill-site, where a fault has been suspected to separate the overlying strata, some 2,068 feet thick, from the mass of shales which underlie the sandstones from this site down McLellans brook to the East river. A checking of the measurements in 1893 made the mass of shales overlying the Main seam up to the mill site 1,520 feet, inclusive of the 1,128 feet of shales lying between the three-and-a-half feet seam and the Main seam according to Hartley, page 67, making a total of some 3,600 feet of strata over the Main seam. Continuing the consideration of the section of strata to the east of the East river, the diamond borehole No. 1[†] of 1878,

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[*] Poole, p. 327.

[†] Poole, p. 305.

Main seam.

put down 1,300 feet due south of the south corner of the Albion 4 square miles area, struck the Main seam, with shale partings and greatly reduced in thickness, at 635 feet. The supposed equivalent of the Deep seam in 31 feet of shales beginning 160 feet lower and of the other under seams is unrecognizable dark shales without coal. It reached the first bed of sandstone at 307 feet below the Main seam correlating the first sandstones in the Albion section just below the Third seam and cut no more coal to the bottom of the hole at a depth of 1,337 feet.* These measurements give a total thickness east of the river to the coal and shales without any sandstones of some 1,830 feet. No approximation of the thickness of conformable measures below the coal series east of the river has been made. The earlier explorations and those of 1878 gave no encouragement to examine them further, the probability being that the strata are less and less bituminous as they approach the margin of the field along Weavers or McGregors mountain.

McLellans brook grist mill.

Logans report describes the neighborhood of the fulling and grist mills on McLellans brook, where no further discoveries have been made, and the small seam there has not been reopened. Some further exposures† were made of the George McKay and other small seams a mile and more east of the brook on the land of A. McLean, without discoveries of moment. The seams there were found to be as high in ash as 18 and 21 per cent. So of the little desultory work to the south on the Mountain seam which underlies them and which is the westwardly extension of the Six Feet seam now extensively worked at the Vale colliery. South of McLeans house and eastward of the water course under the highway, the outcrop of the mountain seam is cut off by the boundary faulting and the overlying seams are hidden under heavy deposits of drift. To the east of the Vale area the new map shows all that is known or suspected of the structure, and folding and crushings along faults have apparently cut off an extension of the field in that direction. On the northeast edge of the same area, among what appear to be the laterals of the great north fault, trial pits have shown coal, but in no case to change the form assumed by Logan for the field at that part.

Whitburn.

Mountain seam

Coal seams east of New Glasgow.

The northern rim of the field east of the East river remains without further development than the map indicates, and later openings on the coal seams were disappointing as to workable beds. ‡ The district evidently is much disturbed, and the thickness of the seams variable, but of the general structure, an idea has been formed that the George McKay and the Fraser Adit coals on the Merigomish road are the same seam, and that the dotted lines on the map south of the latter represent the possible extension of the heavy bed of sandstone crossed by McLellans brook at Widow Chisholms. The contact there of the series of sandstones overlying a series of black shales at Black's mill site agrees with an exposure under the seam at Connollys pond, but the coals are not as much developed.

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*Logan, p. 49.

† Poole, p. 336.

‡ Logan's Report, 1869, p. 44.

Richardson seam.

At the New Glasgow brickyard, the Richardson seam, less than three feet thick, was worked in a small way, but the Stewart seam has not been reopened. On the western side of New Glasgow, about the athletic grounds between the river and Haliburtons pit, some new trial pits failed to throw additional light on the structure and the extent of the faults which disturb it. Followed westwardly along the north margin of the field some trial pits near Oggs quarry, gave the information added on the present map which indicates a broad region of disturbance and serious interference with economic working of the contained coal seams

Difficulty has been experienced in reconciling the undisturbed section on McLellans brook with the structure across the river on the left bank, where at Calders (H. Poole 1863) the change from shales to sandstone is reversed and the former are overlying the sandstone series. It is surmised that the series at Calders may be the equivalents of the beds of the Albion section overlying those which extend from the Colin pits westward to McCulloch brook.

Albion section.

Stellarton or Albion Section.—Occupying the centre of the field, this section is crossed by the East river with the working pits on the left bank. Here the first discovery of coal was made on what is known as the Deep seam cropping out on the brook a little above where the Main was deeply burnt in the unknown past to a distance of 1,000 and 500 feet along the crop on either side of Coal brook. After that to prospect the strata down the brook a costeaning trench was dug and timbered which gave the section of measures published in Haliburton's History of 1829.

The position of the Main seam in McLellans brook, section B, gives the relation of this section to the eastern portion of the field; and the continuation of the main seam beyond the McCulloch fault, is assumed to be the Acadia seam of the western or Westville section.

Hartley's section 4, p. 67 gives 1,128 feet of strata above the Main seam and in all 2,453 feet, down to McAdams' cut on the railway between Stellarton and Westville. Taking this section as a standard very decided variants from it were found in the several pit workings; in the Foord, Cage, McGregor and Fleming shafts, and in the stone drifts (see Poole, pp. 295-304.)

Thickness of coal varies.

The differences in the thickness of the several seams in various parts of the workings have been referred to, and mention has been made of the Main seam with 9 feet of coarse coal near McCullochs brook; 38 feet, nearly all good coal at Dalhousie; and 2 feet only, at the Pictou pit on the further side of East river. Then the Deep seam with partings is 40 feet 5 in., reduced to 22 feet at the Cage pit; fifteen feet 9 in., at the store pits, and represented by black shales only in the Pictou pit neighborhood. The McGregor changes similarly along the crop; thickening also to the deep from 15 feet at the outcrop to 17 feet 3 in., a quarter of a mile down the slope and to nearly 20 feet in total thickness at the axis of the syncline, a mile northward of its outcrop.

In abstract the Stellarton section varies from the following:

	Ft. In.	Ft. In.
Main seam	38·0	
Measures		148·0
Deep seam	40·5	
Measures		106·6 to 45·0
Third seam	11·9	113·0
Measures		to 27·0
Purvis seam	3·0	130·0
Measures		to 109·0
Fleming's seam	5·6	
Parting		to 5·6
McGregor	14·10	
Measures		to 211·0
Stellarton oil coal, etc	5·0	

Hartley's No. 4 section reports the bloom of other coal seams underlying the oil coal that was worked about 1860.(1) These lower seams have not been tested and it is possible that while their outcrops promise little or nothing, they may in sympathy with the McGregor's seam improve to the northward within a limited area about the syncline.

Vale section.

The Vale or McBean and St. Lawrence Section of Logan:—Occupies the extreme eastern division of the field on the upheave of Division A and next underlying strata, so modified in this district as to be unrecognizable as of the same horizon as that of McLellans brook rocks. Over it the upper waters of Marsh brook flow northeasterly until they are deflected at the north fault, and then they follow approximately the fork of the synclinal of the underlying strata which has an inclination in the same direction, while the strata on the right dip more and more steeply as the hill range is approached.

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(1) Poole, p. 298—Hartley p. 76.

Faults, somewhat parallel to the great north fault, come away from the east but are not known to extend beyond the axis of the syncline. They are all upthrows to the north-east, and the Lawson fault of Logan is limited in the same way. The views of Logan, respecting some of the structure hereabouts have been partly modified by subsequent workings, and the section at the Vale colliery is somewhat as follows:

	Ft. In.	Ft. In.
The G. McKay four feet seam with good coal........		2·0
Strata	100·0	
Coal, 2 bands of oil shale and strata..................	507·0	·8
Coal, the six feet seam..................................		6·0
Strata..	700·0	
Coal, the McBean seam.............................		8·0
Strata..	37·0	
Coal..		2·0
Strata, terminating in black shales	304·0	

A continuation of the section is given in Logan's No. 9 section p. 37, on McLeans brook and the changes are noted by Poole p. 335.

Westville.

Westville Division:—Sharply separated from the Albion district by the McCulloch fault proved at the railway bridge crossing the brook of that name, its measures have but a very general resemblance to those of the latter, in the group of seams underlying a great thickness of barren strata. In detail there is little similarity, for the nature of the beds changes with the locality, as already commented on. Deterioration in the quality of the seams along the crops occurs in both directions from the centre of the section in the parts where they are disturbed by faulting paralleling the principal dislocations. The lower seams deteriorate sooner than the upper, and it is supposed that the original lagoon of deposition was narrow and confined between the old rocks of Waters hill and those to the south. In its western extension it was probably also very limited.

On the map of 1869 a small seam is shown overlying the main Acadia seam, but no such seam, theoretically supposed to exist, is now known to have even been actually exposed, and today nothing is known of the half mile of strata overlying the top seam, except of the lower portion, 326 feet, pierced by the Drummond mine pumping shaft. Trial pits since 1869 on the crops of seams underlying behind the Black Diamond mine which operated on the main seam found only coal which was inferior and thinning rapidly to the northward—Poole, 235.

The latest workings ofthe Drummond mine in depth have shown an extension of this Westville district much further to the south-east behind the Albion division than was expected on the evidence of some trial pits on the Drummond area, evidently wrongly reported.

In the Westville, like all other districts of the field, the thickness of the normal bed varies with the locality and the following section is subject to modification :—

	Feet.	Feet.
Strata	26,000	
Coal, Acadia main seam		17
Strata	184 to 260	
Coal		12
Strata	107 to 126	
Coal		6
Strata	90	
Coal		8

The strata underlying the coal seams are exposed on the Middle river and McLeods brook ; but as yet no measurements have been made of those on the river. Since 1893, workings of the Drummond mine have been pushed southward by the fourteenth level as far as the Stellarton reservoir. Here the section of the coal seam is given betow :

Drummond mine.

Coal, fall	2·8
Coal, fall	0·7
Fireclay	0·7
Coal, bench	2·4
Shale	0·6
Bottom coal	3·6
Total in feet	10·2

Culton's adit.

This is at a point more than a mile and a half from the slope mouth, where the seam showed a total thickness of 17 feet. Speculations are now indulged in as to whether connection will be made with the black shale and gray sandstone on the East river near the asylum occupying a position difficult to explain in relation to the strata at the pumping station. To the south of the Drummond mine and in the neighborhood of Culton's adit, boreholes have been put down, drifts driven and much money spent of late years, without changing the conclusions reached by the earlier explorers—that the district is greatly disturbed and is limited by the dislocation which exposes the lower red rocks at the old mill dam a quarter of a mile south of the adit. (Poole, p. 293.) In the adjoining mine, workings approaching the adit from the northward met inferior coal and were stopped before the actual boundary of the field was reached ; but which would appear to be serrated by faults of two series.

Stellarton Asylum.

On the map, the lines dotted to represent the position of the working levels also indicate the extent of the good coal in the worked-out portions which are carried eastward behind the Albion mines workings and to within half a mile of the East river.

Permian.—It has been convenient to call Permian the series of strata younger than the Productive Coal Measures. These are sometimes spoken of as Permo-carboniferous and the equivalent of the highest beds in the famous Joggins section of rocks where no unconformity has been detected. On the other hand, in this field, unconformity below the Permian is most marked and the series is largely developed northward in ascending order up to Cape John and Amet sound where the highest members are preserved under the shelter of the anticline of Wallace.

Highest strata.

This series has for its base the massive conglomerate that extends westward from Merigomish island and which is so well exposed at Greenhill and New Glasgow as to there acquire its distinctive name.

New Glasgow conglomerate.

On Fraser mountain it is overlaid by a concretionary limestone, and an inferior seam of coal. Three other thin seams crop under the slag dump on the north side of Smelt brook, and other small seams at Caribou, Beggs cove, Rear brook and Little harbor, but everywhere valueless, so far as discovery has at present gone. As yet, fragments of coal or black shale have not been found in the congomerate itself but further search is desirable. In it are pebbles of iron ore from the hills to the south, specimens of the large " bulls eyes ", or the spherical calcareous concretions occurring in the immediately underlying sandstones, and at Alma, where it rests on Devonian and its dip is southerly, it contains boulders from the pebble beds which are in situ three miles to the south of it.

Southerly dip of conglomerate.

At present it is popular to express views favourable to the encouragement of boring through the Permian strata in search of Coal Measures carrying workable seams of coal, but the writer was unable during a study of the field extending over many years of residence to find any trace of evidence suggesting a recurrence or a continuance of Coal Measures northward of the well known limits given to the field. There are besides strong reasons for conviction that productive Coal Measures do not underlie a large part of the area covered by the Permian beds as has been suggested,(2) and least likely of all along the southern limits occupied by the lower members of the new formation where the under rocks are visible.

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(1) H. Poole 1863.

(2) Exhibition mineral catalogue, 1902.

Conglomerate.

This basal conglomerate bed of the series, approximately coincides with the northern margin of the coal field and although the conglomerate all but touches the Coal Measures on Blackwood brook near the hospital, a fault certainly intervenes there, as elsewhere along the boundary, and the hoped for overlapping of the Permian on the Coal Measures has yet to be discovered, search so far having only resulted in exposures of a base consisting of either Devonian or Millstone Grit.(1)

It is true, the general structural features of the country do suggest a possible recurrence among the faults north of the hill range, of patches of coal strata, now covered by later deposits, and also that after sufficient study of the system of faulting occurring there has been made, it might be followed up by methodical examination by boreholes piercing the Permian in order to test the character of the underlying series.

Rear brook.

Already a borehole has been put down near the mouth of Rear brook. It entered the conglomerate at a depth of less than 400 feet, and was still in it at 500 feet, where the loss of the drill-head stopped the boring.(2) A previous borehole put down under the direction of Sir J. W. Dawson, lower down the East river and on the right bank had not reached the conglomerate at a depth of 734 feet. Other trials in the same locality are now in progress.

Fossils of this series may be found at the mouths of and up Smelt and Rear brooks. In the latter, below the old mill dam on the brook numerous tracks of a batrachian, *Sauropus*, have been obtained; and above the dam, plants and fish remains, jaws, scales, coprolites, etc.

Minerals.—Specimens of chalcocite with plant remains occur at Caribou and other spots; and pyrolusite is found in small quantities in the conglomerate at Alma bridge.

The silicious beds supply grindstones and building stones of good quality.

Igneous Intrusions.—There was a time when volcanoes were very active in the neighbourhood, when liquid rock was forced upward and consolidated among the beds that had previously been formed as sediments under water.

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(1) Haliburton, 1863.

(2) A second boring by rope and free fall cutter is still in conglomerate at a depth of 1900 feet.

REFERENCES.—Geol. Sur. Reports, 1886, Vol. II, P. p. 93.
" " " 1889-91, Vol. V, p. 108.
Geol. Surv. Report, 1866-9. pp. 13, 64.
Acad. Geol., pp. 129, 322, 343.
Trans. N. S. Inst. Sc. Vol. 1, p. 36—1879, p. 193.
Ser. 2, Vol. I, p. 273.

Volcanic rocks.

Among the oldest rocks to the south, the more ancient lavas are largely represented; others disturbed the Cambro-silurian, and then, sometime subsequent to the Silurian epoch, a great activity prevailed along the southern rim of the coal basin. Exactly at what time the disturbances ceased has not been made out, but it was before the Carboniferous Limestone period, for we find boulders of trap in the conglomerates of that age. These rocks are easily recognized in the bare, black protuding peaks of McLellans mountain, and in the bold escarpment overlooking the East river; some of them are vesicular with and without amygdules; others are compact. The greenish felsites of the Devonian at Horn's bridge which spans McCullochs brook are classed among igneous rocks.

Glacial deposits.

Glacial deposits.—While the palæozic division of the clastic rocks is well represented in the province and very fully in the neighborhood of this coal field, the Mesozoic has only an equivalent of the lowest Triassic given to it and the Tertiary is absent. During the long hiatus, the region seems to have been out of water suffering erosion and for much of the time existing as a high plateau. It is true, it has been suggested that Miocene deposits may lie off the coast, but with this doubtful exception, none other than the pleistocene occur.

Ice action.

Of this later age, deposits under varied conditions may be observed in the district, well worn erratics, angular boulders, displaced slabs, clay, sand and sharp edged fragments of local rocks without arrangement, on the hills, in hummocks on the middle ground, in drumlins or as ground moraines in the low lands and valleys. All have a set from the high to the low levels and northward towards the waters of the Gulf of St. Lawrence. The waste from the great conglomerate ridge has been carried down stream to the northward. The glacial striæ on the planed tops of the Cambro-Silurian hills point N. 42° E. (Magnetic). Coal wash has been found by prospectors carried to the north beyond the limits of the coal field. Undoubtedly, the last stage of the ice-age in these parts of the province was a glacial movement northward. Of the great continental ice movements southward, which it is assumed preceded the local records enumerated, no evidence has been detected, with the possible exception of the finding by the writer in a brook in McLellans mountain half a mile south of the coal field of a few well worn pebbles of bituminous bat, presumably drift from the north. A large erratic of doubtful source, possibly Cobequid, lies on the steep grade out of Stel-

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Glacial deposits.

larton on the railway to Westville. Drumlin ridges are crossed by the road from Stellarton to Asphalt. Lenses of clay and sand have been exposed and taken for use from the hill at the Back mines, where falls of roof in the pits have crushed through to the surface and exposed them· These deposits are remarkable for containing at the same time fragments of coal and black shale from the immediate locality together with some stones brought from a distance. Terraces of the till, to a height of 150 feet, made more noticeable by slight falls of snow are seen on the right bank of the East river where it opens out into the coal field and seemingly mark the margin of a temporary glacial lake or a flooded condition of the plain. A secondary separation of the sand in the till occurred in the later stages of the period and deposits of it were made along the river to some height; as at the mouth of McLellans brook up to a height of 100 feet, and in this sand deposit under a cover of ordinary drift of earth and stones, are lenses and balls of clay with boulders; and pebbles of travelled stones, with pockets also of black shale, fragments evidently torn from the adjoining bank.

Till retards prospecting.

When exploring operations are conducted in this field, serious obstruction is often caused by the depth of the superficial deposits, which being glacial drift, give little indication of the nature of the rocks underneath. In fact, their contents sometime mislead; e. g., the abandoned Drummond mine branch railway near the Fox brook road passes between outcroppings of reddish sandstone, evidently older than the Coal Measures. These were assumed to be in place until mining below in coal, differently dipping, proved the rock to be but a very large drifted slab. Again in 1890, the finding of large blocks of coal in loose ground just north of the Vale area caused it to be assumed that the place was within the limits of the coal field until a trial pit disclosed red rocks in situ. In this case also the drift had evidently been from the southwest; in the same direction in which lie the ridges and ground moraines and from which the striæ point.

Deep boulder clay.

At Stellarton a depth of 60 feet of boulder clay has been met with, while at Westville as much as 86 feet of till had to be passed through to reach bed rock in one trial pit. It has been assumed that the glacial erosion in the neighborhood was excessive, but the structure of the surface points rather to long continued preglacial denudation directed by the faulting and texture of the rocks; the subsequent ice action playing but a minor part in shaping the surface by re-arranging the soil and stones and loosely transported material.

Progress of the Mining Industry:—In his history of Pictou county Dr. Paterson tells of the discovery of coal in 1798 on a brook near where the Cage pit was sunk by H. Poole in 1853, and where the crop of the Main seam has been burnt at some remote period; but when this and other surface fires began, inquiry has failed to discover.

Historical notes.

The earliest workings (1) were along the out-crops of the seams and the coal was hoisted by horse gins. Then followed the series of pits in line and close together near the East river in the strip now known as the Burnt mines. In 1839, other pits now distinguished as the Crushed mines were sunk to greater depths with a winding shaft for each level; and from the lowest inclines won coal lying to the deep. Subsequently, in 1867, the vertical Foord pit, 900 feet deep, was put down. In the course of operations, numerous small faults were met with and recorded. Their method of occurrence and grouping were mapped in 1893 in the paper read before the N. S. Inst. of Sc., and are worth examining.

In the Main seam workings, west of the Forster pit, at a depth of 900 feet a deterioration of the seam both in thickness and quality was found; and as already mentioned a similar experience was met within the opposite direction.

Deterioration is also found to occur in all the seams of the Stellarton series eastward of the East river and they are apparently affected by approach to the old rocks which formed a shore to the Carboniferous deposits. Similar modifications in the composition of the strata, such as substitution of sandstone for shale, shale for coal, find in this field numerous illustrations that should prove instructive to the prospector. Further reference to some of these changes are elsewhere noted.

It was in this district that the first foundry east of Halifax was erected in 1828; The first cast iron was reduced in 1829 in a small special blast furnace; the first locomotive on a railway in Nova Scotia ran in 1839; and the first steamer to cross the Atlantic from Canada leaving Quebec, called at Pictou for Albion coal.

In the use of machinery, the practice of coal mining in this field has taken note of the gradual passage from appliances at one time generally employed to those now regarded as up to date. A few examples may be thus noted:—

Then—Ropes for winding coal were flat, of hemp, or of iron wire:

Now—They are round, of steel and of high tensile strength:

Then—The winding in shafts was slow, the skips swinging free against spilling boards:

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(1) See also Trans. Mining Soc. Vol. II, Part 2, 1894.

Now—There is a rapid winding in cages with guides and perhaps springs and safety catches to ease the shock and prevent over winding:

Then—Shafts were numerous, close together on the direction of the dip:

Now—New pits and the haulage is concentrated from long distances to central points:

Then—Ventilation was by firelamp and furnace:

Now—By mechanical fans of high speed, and high water gauge:

Then—Open lights were general and the "sulphur" man used the single gauge Davy safety lamp:

Now—Safety lamps are generally used, and are of double gauge with glass rings:

Then—Boilers of low pressure, hay stack in form:

Now—Of high pressure, flue or water tube.

Then—Engines vertical with a beam of slow speed:

Now—Of high pressure and rapid, sometimes compound with cut off.

Then—Coal was carefully built by the miners on skips made with bales and loose iron rings. The skip separate from the rolley that carried it from the gate road end to the shaft was dragged on its runners from the working face to the rolley way. The rolley had edge wheels wedged fast on square iron axles:

Now—Pit boxes, hutches or mine cars with chilled flanged wheels shrunk on round steel axles bring the coal from the working face.

Then—On banking, the skips were tipped by main strength, the iron rings tumbling with the coal on to the screens to be gathered and carried up again to the pit head:

Now—Cages automatically discharge cars to automatic tipplers which discharge over moving screens and picking belts, all engine driven.

Then—Coal cutting was an art, the collier took pride in his ability to handle the pick, to cut a straight and narrow shearing, to make a low holeing deep.

Now—A neat wall is only seen in old workings; rough, ragged and irregular sides are accepted with the urgent demand for large outputs.

Mine phenomena.

In this district the miner will find examples of both thrust and creep irregular pressure from irregular working of overlying seams; fireclay between benches of coal squeezing out by pressure as clay out of a brickmaking machine; lateral pressure on the coal walls of inclined seams reducing the space of openings 30 p. c. in a few months, sagging the roof and causing it to break even over ordinary booming in less time; places so closely timbered that neither rock nor coal, nothing but blocks of wood, are to be seen for long distances, except at the actual faces. Studies are now made in faults, types, infiltrations, substitution of coal bat shale and fire clay; in reed or cleat structures; in so working as to make the pressure release masses of coal with the least labor to the miner; in the proper setting of timbers; in estimating the strength of big and small timbers under varied conditions when under end and side pressures; in the spalning of the ribs, and how to guard against it; in how to distinguish between sounds which are benign and those premonitory of danger—so expert do those extracting pillars of coal become that they work on to the last minute before a fall of roof takes place and even amid conditions appalling to the inexperienced. Among the exceptions to the usual pastimes indulged in by miners a "bon spiel" was played 300 feet underground in 1854.

Studies.

System of working.—Time has seen many variations in the methods of mining introduced and practised to meet altered conditions in angle of inclination, thickness of coal extracted and in the strength of the roof and floor strata. Where the roof was strong near the crop, the openings were large, the standard width of six yards being often exceeded; and the pillars of coal left to support the roof were small, (but a few feet in some places) and yet they held up for years. Necessarily with a dip of 18° or over, the rooms or bords were driven parallel with the strike and were connected in sets by diagonal horse slants. As laid off the proportion of pillar to opening stood well enough even to a depth of 500 feet, until the balance was lost at a weakened spot and then there was a crush. The workings initiated in 1839 toppled over and became the crushed mines of 1852. At equal depth, thicker pillars also yielded to an increased weight brought on by subsequent pillar robbing in the Dalhousie workings; while at much greater depths no proportion would maintain the openings, and now at depths of 1,200 and over, operations are so conducted as to bring on an immediate settlement; levels which would not remain open for three months timbered at nine feet wide are now driven twenty feet and packed on both sides of the hauling roads. The present system for the inclined seams being to drive levels in pairs every 400 or 600 feet apart, with balances to the full rise every 380 feet, and to have the panel of coal so blocked out, removed longwall advancing. Every set of four men have a road between close packs for a face of twelve

Old method of working.

yards. So worked it is literally true that the seam of coal, except at the face, cannot be seen for the timbers used to maintain the roof and sides of the excavations.

Mine gases.

Firedamp.—The mines of this field produce more explosive gas than those of the other districts of the province, sometimes by general exudation from the coals, sometimes in considerable volume from "cutters" in faults. One such in the Foord pit bubbled out of water so violently that the voice near by had to be raised to be heard. From freshly cut coal, gas has been known to flow round the corner of a pillar so pure as to put out the flame of a safety lamp held in it, and that too where there was a current passing of 10,000 c. ft. of air per minute. On one occasion when leaning against the solid coal enough gas issuedfrom the wall on the lea side of the writer's body to put out his light, although a strong current of air was circulating at the time. Another instance of freer evolution of gas might be given. A pair of levels advancing in the solid coal made so much gas as to foul a current of 10,000 c. ft. per minute and make it advisable to stop further operations at the place for eighteen months until the feeder of gas pined off.

Of this locality Mr. R. Smith, before a select committee of the House of Commons in 1835, remarked:—

Evidence or gas.

'The ebulition of firedamp at the East river was similar to that of a steam boiler, with the same kind of rapidity, so that putting flame to it on a calm day it would spread over the river, like what is commonly termed setting the Thames on fire; it often reminded me of that saying. It is very common for the women to go to the river with the washing they have to perform for their families and dig a hole about ten inches deep by the river side. This they then fill with pebbles and then put a candle to it; by this means they have plenty of boiling water.' I mention this to show how highly charged the coal was with gas. When we first reached the seam at a depth of 180 feet, the gas roared as the miner struck the coal with his pick; it would often go off like the report of a pistol. The noise which the gas and water made in issuing from the coal was like a hundred thousand snakes hissing at each other.'

To diminish the danger arising from so much gas, the use of black powder and open lights of late has been abolished, but previously several accidents occured and fires resulted. Three times between 1828 and 1839 was the river turned into the workings to extinguish fires; and other fires after 1860 also required to be drowned out. In the meantime, it frequently occurred that gas was set on fire in the course of working and so to guard against ill effects, puncheons of water were kept in each bord with bags for beating out the flame, or by the use of small cannon to fire at the flame and extinguish it by concussion. Then it was that the fireman in his rounds before the day shift began work thought nothing of hooking his bicket lamp to the cleaning rod and reaching up to the high places get rid of gas that had accumulated by setting it on fire.

Fires in mines

In 1896 a commission was appointed by the Provincial Government to report on the Mine Fires of Pictou county, one of which had been burning since 1870, and continues to this day. This report is of interest to those whose local knowledge enables them to read between the lines. It was published and subsequently subject to comments in Appendix 21 of the Journals of the House of Assembly, 1890. A paper discussing it was also read before the Mining Society and published in the Transactions of the Federated Canadian Institute for 1897.

Blackdamp.—This product of decomposition is met with in old workings. In 1900, on re-entering the lowest lift of the Deep seam, after it had been closed for 20 years, cars, harness and canvas cloth were found quite sound; tools, such as saw, pick and shovel being in such good order that the explorers were able to use them, and even some hay was still springy under foot, so well had the carbonic acid gas guarded the contents from oxidation even in the dampness of the mine.

In the laboratory and class room the student is taught the diffusion of gases, but in the practical work of the mine, he finds the gases have a tendency to keep separate, of blackdamp to lie in depressions and firedamp to collect in cavities overhead. When explorers in 1849 entered the Burnt mines and took a current of fresh air with them they found themselves wading in places through blackdamp, while inflammable gas was within reach overhead.

Accidents.

Accidents.—Many have been the losses of life and property in these pits, many the narrow escapes. Of the latter, one will suffice to mention. The sinkers had gone to bank, and but one man remained below to fire a shot. The cotton was lit, and at the signal the gin horse sprang away, but the slack of the rope caught and the bowk with the man in it remained suspended over the shot. Instantly realizing his position the miner threw his bonnet and with true aim knocked out the snuff from the priming while the men on top waited for the blast in dread of the results.

Mining disasters.

From falls of coal and roof and in miscellaneous ways accidents have happened, but the greatest disasters have been from explosions of gas. The Drummond mine in 1873 claimed 59 victims, including four

Accidents.

brave volunteers who gave their lives to aid those caught in the first explosion. In the Foord pit, 6 were lost by an irruption of water and 44 by an explosion a mouth later in 1880. Two serious calamities attended operations in the McBean seam; a runaway car on the slope killed 8 men in 1883 and an explosion 13 in 1885. Two brothers and a companion at the Marsh were destroyed by dynamite, and two shaftmen fell with a broken rope in the Foord pumping pit. Among the miners, premonition of disaster has had credence given it by authentic cases of men who, having decided to give up the mine, were known to have gone below with the intention of squaring up their places or gathering up their tools and who never returned alive. There was a general anticipation of explosion, naming as it so happened, the very day of that of the Foord pit in 1880, and there is on record with the Psychical Society a letter by one Wyllie telling that the common talk at Springhill was of an expected explosion in the spring of 1885 and the letter was received just before the disaster of that year occurred. It is only right to also mention that there have likewise been a number of forecasts among the mining villages that never materialized.

MINERALS.

Analyses of coals.

Coal.—Many analyses of Pictou coals have been published: by Prof. Johnson 1843; by Dr. Dawson in his Acadian Geology; by Prof. How, in the Mineralogy of Nova Scotia, 1869; in reports of the Geological Survey, Logan, 1869, p. 365, etc., etc.*

They all go to show that the composition of the several coal seams varies in the several benches and in various districts of the same seam. The ash is usually above 7 per cent. white and bulky; the coals of the lower series west of the East river are coking; while those of the higher series east of the river are non-coking. The clean coal of the principal seams is low in sulphur, under 1 per cent, and hence is valued by the worker in iron, the furnace man and the guardian of the domestic hearth.

Fireclay.—Associated with the coal seams, as well as in and under them, are beds of clay, often bituminous, slickensided and generally free of silica. Many contain nodules and masses of clay-ironstone easily separated on weathering.

For ordinary purposes, some of these beds of fireclay are suitable and have for many years found colliery uses; others are too high in alkalies for fire-brick, as for instance, the bed overlying the Deep seam which contains about four per cent.

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* Geo. Sur. Rep. XV, Part S, p. 82 and XI, S, p. 52.

Minerals of coalfield.

Alum salts.—On weathering, the waste heaps on the surface show sometimes an astringent efflorescence and the Acadia slope develops stalactites of melanterite from the roof shale.

Brine.—Is met with at depths below 1,000 feet in the Acadia and McBean seams.

Calcite.—Incrustations have rapidly formed from seepage in the McGregor seam, taking the form of cockscombs.

Pyrite.—Filamentous, cockscomb, sometimes in the form of marcasite or massive, infiltrating vegetable tissue or occupying cavities of the nodular ironstone irregularly dispersed, or as lentils, but lying horizontally in some of the coal seams. (1)

Galena and zinc blende.—Have also been found in nodules in the measures.

Clay ironstone.—In nodules and in bands as already noted.

Blackband ironstone.—Occurs where cannel comes in under the upper four feet bench of the Deep seam.

Specular and spathic iron ores.—Show in very thin veins at Fishpools on the East river.

Limonite.—Within the bounds of the map at the contact of the older rocks with Lower Carboniferous of Waters hill, Smokey-town.

Hematite.—As pebbles in the New Glasgow conglomerate, and even plentiful as small boulders of the ore in the conglomerate on Sutherlands river. Their source is a matter of speculation, although thick beds are known in the Silurian rocks to the south.

The copper ores, chalcocite and malachite.—In nodules or associated with plant remains in certain beds of the Permian sandstones.

Limestone.—The Coal Measures and Millstone Grit beds are seldom calcareous, but the pavement of the Geo. McKay seam is an exception. Over the New Glasgow conglomerate a distinctive band of concentrically botryoidal limestone marks that horizon, and suggests synchrony with the bed at Matheson's on River John. Calcareous bands largely occur in the lower formations, and the massive beds of the Lower Carboniferous furnish lime for local use and limestone for the iron furnace at Ferrona.

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(1) Geol. Surv. Report, 1873, p. 109.

Minerals of coalfield.

Gypsum.—Occurs on Waters hill, on McLeans brook east of Thorburn, and near the church at the base of Green hill. Larger deposits are found up the East river.

Building stone.—Few of the beds of the coal measures yield good sandstone fit for ashlar, but some layers find a use for foundation work. From the Millstone Grit, more regularly bedded stone of uniform grain is obtained, but the source of the most evenly bedded and the fines quality of stone is the higher series classed as Permian.

Grindstones.—Are made from the sandstones of the Permian at Little Harbor.

Petroleum.—Blotches of strongly smelling grease, encased with calcite occasionally are noted in the clay beds between the coal seams; and inspissated drops, generally nonelastic, are found with dog-tooth spar in the quarry at the East river ford south of Stellarton; in the limestone nodules of Fraser Ogg's quarry and in the calcareous floor of the George McKay seam.

Oil shales, Oil coal, (1) Stellarite. Curled and slickensided clays, with a brown streak, were worked at several places in 1860 for the oil they produced. On McCulloch brook north of the railway bridge, at the district of Asphalt, at Stellarton, etc. Elsewhere the compact cannel-like and compact shale bands were prospected, all yielding some oil.

Picked samples of oil coal gave 190 gallons to the ton, cargoes assayed 54 gallons while the shale or bat produced 44 gallons.

Brick clays occupy the flats where waters were pounded during glacial times and they have been worked by the brickmaker at several places.

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(1) Trans. N. S. Inst. Sc. Vol I. p. 36, Vol. VIII 1893 p. 340; Geol. Surv. Report, 1869, p. 378.

GEOLOGICAL SURVEY OF CANADA

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THE ARTESIAN AND OTHER DEEP WELLS

ON THE

ISLAND OF MONTREAL

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The Artesian and other deep Wells on the Island of Montreal.

I. Introduction.

II. Some General Facts concerning Artesian Wells.

III. Sketch of the Geology of the vicinity of Montreal (with geological map of the district).

IV. List and Description of the Wells which have been sunk on the Island.

V. Chemical Composition of the Waters obtained by boring.

VI. General Conclusions.

THE ARTESIAN AND OTHER DEEP WELLS

ON THE

ISLAND OF MONTREAL

INTRODUCTION.

During the past fifteen years a large number of borings have been put down along the eastern side of the Island of Montreal, for the purpose of obtaining water. Most of these have been located in the city of Montreal while some of them are situated in the suburban districts, and in most instances large supplies of good water have been obtained. In other cases, however, the water obtained was saline in character, while in still other cases, little or no water of any kind was found.

Importance of artesian water.

This source of water supply in the district about Montreal bids fair to assume an ever increasing importance in the future; and it has therefore been deemed advisable to gather together all the facts which it is possible to secure concerning the borings which have already been made—more especially as much of this information if not now obtained and recorded will be permanently lost—and at the same time by a study of the geology of the district to ascertain what light may be thrown on the character and origin of the subterranean water supplies and the probability of obtaining water by further borings.

It is also of great importance to ascertain, if possible, whether any definite water bearing horizon or horizons exist in the subjacent strata. If there be such water-bearing horizons, it is of the greatest importance to ascertain their depth below the surface in various parts of the area, since, knowing this, it would be possible to determine where and at what depth one could rely on obtaining water by boring. Work of this kind in many other districts, as is well known, has resulted in the discovery and development of water supplies of great extent and of inestimable value.

If, on the other hand, definite water-bearing horizons prove to be absent, much may be learned from the geological structure of the area with regard to the general probability of securing water by drilling.

Accordingly for some years past the Geological Department of McGill University has been collecting information and data bearing on the artesian water supply of the Island of Montreal. Nearly all the deep wells on the island have been visited and all data concerning them which it was possible to secure has been collected and tabulated. The borings have been made with the ordinary percussion drill. No diamond drill holes have been put down and, consequently, no proper cores of rock have been obtained from the bore holes. In most instances no detailed logs of the borings have been kept and no samples of the material obtained from the wells have been preserved by the drillers.

Method of boring.

Samples from a few of the wells however, have been secured and were of the greatest value in supplementing and extending the knowledge of the succession of the underlying strata obtained from a study of the surface geology of the district.

In this report the endeavour is made to present as complete a description as possible, of every boring which has been put down on the Island of Montreal up to the close of the year 1903. Eighty-nine holes are included in the list. It is believed that the list is complete, but it is possible, that notwithstanding the diligent inquiries which have been made, a few wells may have escaped notice. If such be the case, the authors will regard it as a favour if anyone knowing of such omissions will give information concerning them to the Geological Department of McGill University. The Department will also be very glad to have any information concerning new wells which may be bored in future.

Number of wells bored prior to close of year 1903.

The analyses of the waters which are presented, are in most cases incomplete and therefore not wholly satisfactory, having been made by different analysts and chiefly for the purpose of determining the general character of the water obtained or its suitability for use in steam boilers, &c. In making analyses of waters the amounts of the several bases and acids present are determined, but the way in which these are combined must be left to a certain extent to the judgment of the analyst. In the case of the analyses presented in this report a uniform plan has not always been followed by the various analysts in combining the substances found, and thus the analyses are not always readily comparable with one another. No attempt, however, has been made to recalculate them as in most cases the data for this are insufficient.

Hard and soft waters.

Waters are referred to as Hard or Soft according to whether they contain large or small amounts of lime and magnesia salts in solution.

These may exist either as carbonates held in solution by carbonic acid or as sulphates. In both cases the water is hard, that is, it requires much soap in order to make a lather, because an insoluble compound is formed by the union of the lime or magnesia with the fatty acid of the soap. But in the first instance the hardness is said to be Temporary because it is removed, by boiling the water, when the carbonic acid holding the carbonate of lime in solution is driven off and the salt precipitated, whereas in the second case the hardness cannot be thus removed and it is accordingly termed Permanent Hardness.

In order to ascertain the amount of the hardness, a simple method was proposed by Dr. Clark, which consists in ascertaining how many measures of a standard soap solution are needed to form a lather with a gallon of water. The hardness of the water as determined by this method is expressed in degrees.

With a few exceptions, the borings referred to in the present report have been drilled by Mr. Wallace Bell of Montreal, and to this gentleman, as well as to his partner Mr. William Bell, we are indebted for much information concerning them. We are also indebted to the owners of the various wells who have in all cases readily supplied us with all the facts in their possession concerning their respective properties. To all these gentlemen, as well as to Dr. J. T. Donald of Montreal and to Mr. John R. Barlow, City Surveyor, we desire to convey our most sincere thanks, at the same time expressing the hope that the information collected and here set forth may be of service to them, as well as to others who may in future contemplate sinking for water in this district.

The publication of the work having been undertaken by the Geological Survey of Canada, it appears as a Report of this Department.

SOME GENERAL FACTS CONCERNING ARTESIAN WELLS.

Movements of underground waters.

Before considering the records of the Artesian wells on the Island of Montreal, it seems advisable to review some of the conditions by which the occurrence of underground waters are affected. While it is proposed here to treat of these conditions only in a brief and general way, the reader who wishes further information is referred to a more extended description by Prof. T. C. Chamberlain, entitled 'The Requisite and Qualifying Conditions of Artesian Wells',* and to a later report by Mr. N. H. Darton, on 'Artesian Well Prospects in the Atlantic Coastal Plain Region.' †

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*Fifth Annual Report of the U. S. Geological Survey, pp. 125-174; 1885.

†Bull. No. 128, U. S. Geological Survey; 1896.

Curious views concerning these in former times.

In former times, before geological investigations had led to a knowledge of the character and structure of the earth's crust, many fantastic and amusing views were entertained concerning the movements of water beneath the surface of the earth. The origin of springs was an especially fruitful source of speculation, the general opinion being that great holes existed in the floor of the ocean, into which the sea water ran, which water after pursuing a devious path through underground channels, emerged at the surface of the land in the form of springs. The Maelstrom, off the coast of Norway, and other well known whirlpools were supposed to owe their origin to the rapid downward passage of great volumes of sea water into such holes or caverns. In this way it was supposed that the sea was prevented from overflowing, notwithstanding the immense volumes of water which were continually poured into it by the thousand rivers flowing from the land, the part played by evaporation in the case of the ocean waters not being as yet realized. Many ingenious hypotheses were also put forward to explain the supposed upward movement of the water from the ocean into the hills where it appeared as springs* and also to explain the fact that spring water was fresh while the waters of the ocean were very salt.

Value of geological study.

With the rise of the science of geology, however, based on an increasing knowledge of the structure of the earth's crust, underground waters came to be recognized as having their source and origin in the rain which falls upon the surface of the earth, while their perplexing movements became so clearly understood that it was possible in many cases to predict where they existed and where they might be brought to the surface by properly placed borings.

It is now well known that the precipitation in the form of rain and snow which falls upon the earth's surface is disposed of in three ways :—

1—A portion of it drains off the land, finding its way by brooks and streams into the rivers and thus to the sea.

2—A second portion rises in vapour and is returned to the heavens as mists and clouds.

Underground waters have their source in rainfall.

3—Still another portion sinks into the earth's crust and disappears from view.

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* Compare Butler, "A Satire on the Royal Society"—

"What is't that makes all fountains still
Within the earth to run up hill,
But on the outside down again,
As though th'attempt had been in vain?"

The relative proportion of the precipitation which is disposed of in these three ways respectively, varies greatly with the character of the surface and the climatic conditions of the area on which the precipitation takes place, but it may be stated, speaking very generally, that in regions of temperate climate, about one-third of the precipitation is disposed of in each of the three ways mentioned.

That portion of the rainfall which sinks into the earth's crust here alone claims our attention. This water passes down through porous strata or in cracks and fissures, thus giving rise to a system of subterranean water circulation, and finally comes to the surface again at some lower level in the form of springs, or passing out into the sea along the continental margins is lost in the waters of the ocean.

Artesian wells are artificial springs

In some localities, it is possible by boring, to tap these underground water supplies, thus bringing water to the surface in the form of Artesian wells, which may be regarded as artificial springs. One simple case of this is shown in the drawing presented in Figure 1. Here certain beds of differing composition are seen interstratified with one another. The beds A and A¹ are clays or shales, while the bed B is sand and gravel or their more compact equivalents sandstone and conglomerate. These rocks, originally laid down in horizontal beds, have been curved by pressure developed in the earth's crust, which curving has given to the area the form of a basin. The beds are tilted on either side at such an angle that they are exposed on the surface with the outcropping edge of B at a greater elevation than the surface of A. A and A¹ on account of their composition and texture, are practically impervious to water, and being in direct contact with the pervious or porous bed B, they act as confining beds which prevent the water which passes through B from escaping either upwards or downwards. These three beds present the features found in one class of channels through which underground water moves. The water enters the bed B at its outcrops ab and cd, and flows down the dip of the

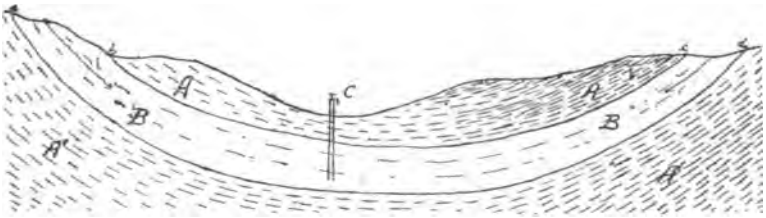

Figure 1. Showing a synclinal fold with a porous bed between two impervious ones.

stratum. If however, the bed B is tapped at a point C by a boring, the water will rise to the approximate level of the ground water in B at ab and cd. The supply of water thus obtained will constitute an artesian or flowing well. If, however, the upper bed A, from extensive fissuring or a somewhat porous texture, be not water-tight, the pressure will be relieved and the water will follow the more easily accessible channels through A to the surface, thus lowering the efficiency of the well at C. The head has in many instances been so reduced that the water will not rise to the surface but must be pumped. In such cases as these there must be a sufficient rainfall, and where the porous bed B outcrops, there must be a considerable area of the bed exposed. For instance, if the rainfall is the same at both the outcrops of B on the opposite sides of the basin, then ab, being more extensively exposed than cd, will furnish a greater supply of water.

Various types of structure in earth's crust which render artesian wells possible.

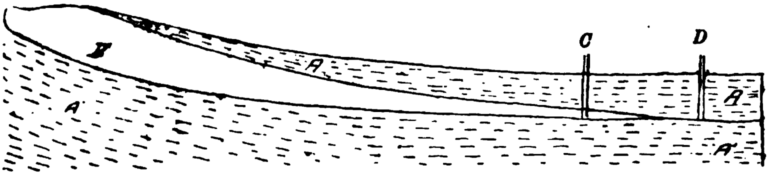

Figure 2. Showing the pinching out of the porous bed B. (Modified from Darton.)

Another type of structure, and probably a more common one than that previously discussed, is shown in Figure 2. In this case there is no basin but a monocline or a long slope of the beds in one direction The porous bed B thins out and finally disappears, with a concurrent thickening of the impervious bed A. In such an instance a boring at C would be successful, while at D no water would be obtained. This structure obtains throughout the great coastal plain which forms the eastern margin of the United States, from New Jersey southward, and from it immense supplies of artesian water are obtained.

Again, the character of the surface drainage may be such as to interrupt the passage of underground waters, as shown in Figure 3, where a cross valley interrupts the water-bearing stratum. Little or no water would be obtained at B, while at A on the lower side of the valley a successful well might be sunk. The water in the upper part of the bed about B would escape and probably form springs along the valley side at C. This is a condition frequently met with along the western border of the coastal plain in Maryland and southern Virginia.

Another case which is sometimes found is illustrated by Figure 4. Here the water-bearing zone, instead of being broad and continuous, is broken up into several narrow beds, which are flatly lenticular in cross section. Boring would give satisfactory results at C, but negative ones at D.

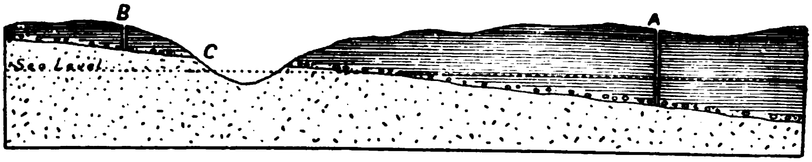

Figure 3. Showing effect of surface drainage on a porous bed. (After Darton.)

Many other types of underground drainage might be mentioned, but the above will suffice to explain the main conditions which affect underground waters traversing porous beds.

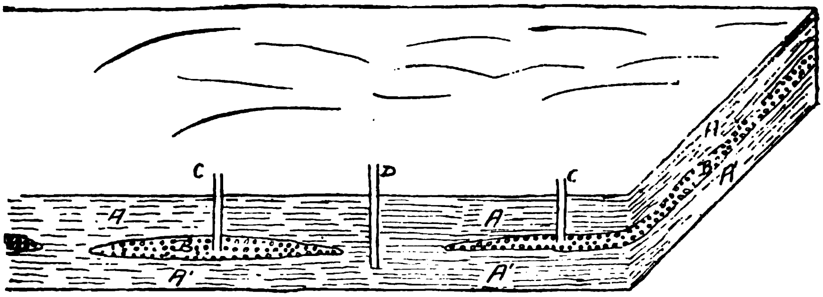

Figure 4. Showing the discontinuity of the porous stratum. (Modified from Darton.)

Artesian waters have however sometimes been obtained in districts which are underlain by rocks of a more massive character than those which we have been considering, such as compact limestones, granitic rocks and crystalline schists. The underground water in these cases flows through cracks and fissures and not through porous beds. This type of subterranean conditions is rudely represented in Figure 5, where the rocks at A are massive and crystalline, overlain by compact limestones, B. The gathering ground is the outcrop of these rocks at a, b, c, and the irregular lines indicate the courses of the subterranean water circulation which takes place through fissures. The supply of water in this case will not depend upon the amount of rainfall alone, but will be influenced by the extent of the subterranean erosion which the country has undergone, by which the fissures and joint planes have been enlarged and deepened, so as to permit the passage of large quantities of water along their course. In this instance a well sunk at C would tap one of an upper series of fissures, and the capacity of the well would be further increased if the boring were extended to the lower level at C'. On the other hand, the boring at D would miss the water-bearing fissures by perhaps only a few feet and would consequently be dry, as would also that at F. At E water is obtained from a lower series of fissures. The materials held in solution by the water in such a district would probably vary considerably, the variation depending upon whether the source of supply was in the crystalline rocks or in the limestone, as well as on the length of the underground channel through which the water had passed.

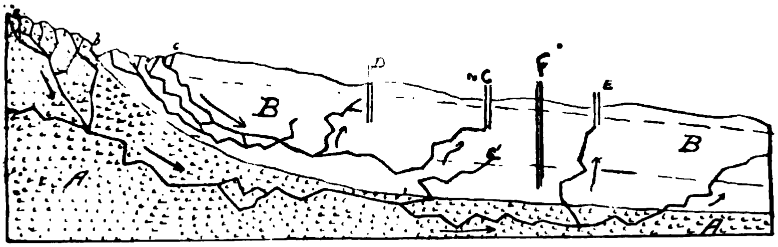

Figure 5. Showing the course of underground waters along fissures.

In Figure 5 the lower water-bearing fissures heading in the crystallines would probably contain soft water and rising directly through the limestones at E would be little influenced by the character of the latter rock. This would serve to account for soft water when found in limestone districts. On the other hand, underground channels heading in the limestone or traversing that rock for long distances would probably be hard and perhaps also saline or sulphurous. The well at C would supply such a water. If, however, the well were deepened to C′, a composite water derived partly from the lower set of fissures and partly from the upper would be obtained.

Underground waters flowing through fissures.

In the case of waters whose underground flow is through fissures, a great variation must always be looked for in the height to which the waters will rise, not only in adjacent holes tapping different sets of fissures whose gathering grounds may be at very different elevations above sea level (as a, b, and b, c, in Figure 5), but also in holes which tap different fissures of the same series. It will thus be seen that in such an area no definite predictions can be made concerning the finding of water, owing to the irregularity in the course of the water-bearing fissures. Even if the fissures be only a few feet apart

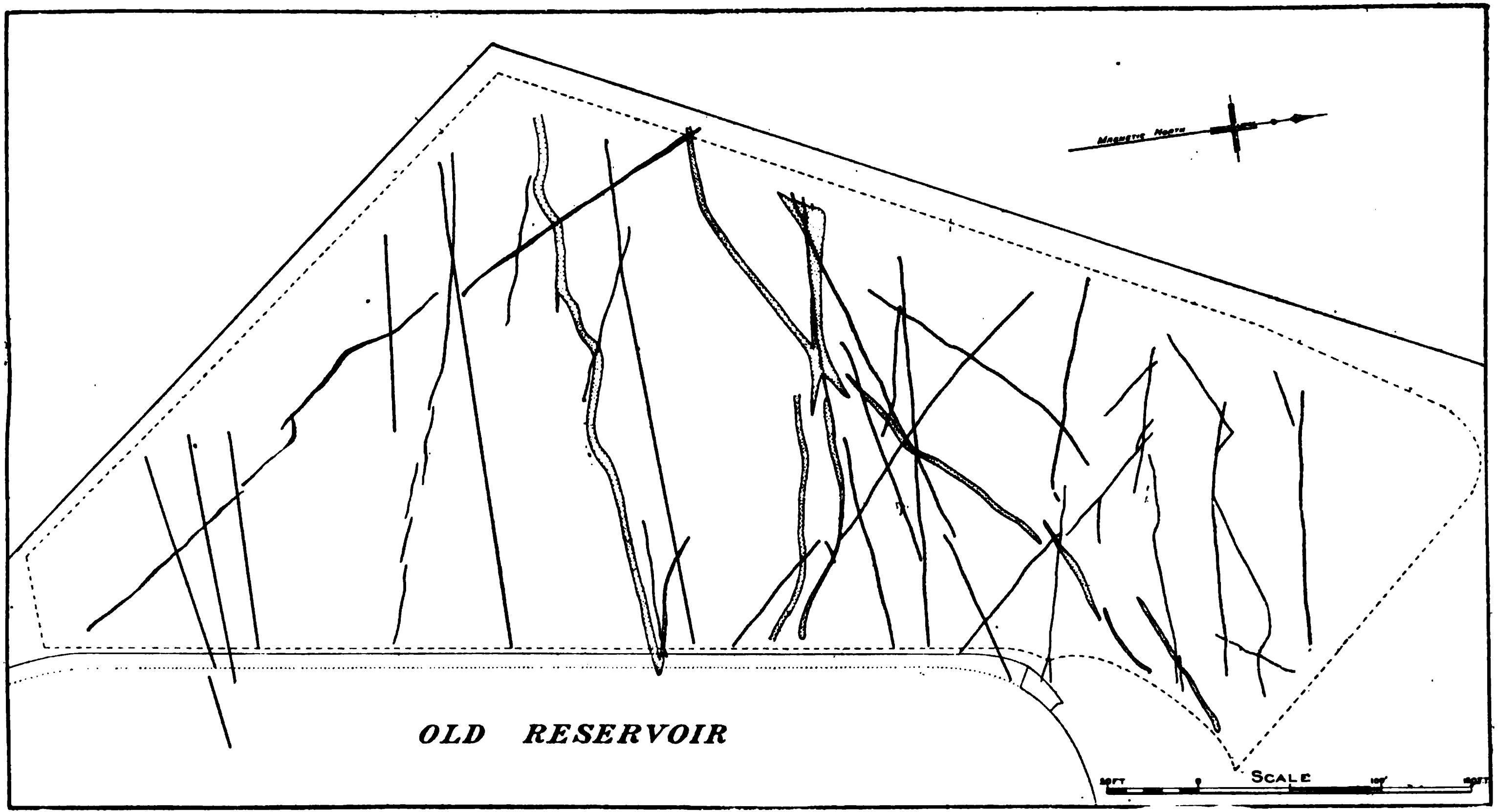

Figure 6. Map showing the dykes which cut the Trenton limestone at the Reservoir Extension, Montreal.

the number of unsuccessful wells will still be large. But in the case of dry wells, as D, it might be possible by shattering the wall rock at some point along the course of the bore hole, making use of explosives, to open up a communication with some adjacent fissure and thus secure a supply of water.

A striking example of waters occurring in this manner is afforded by the islands off the coast of Norway. From the old crystalline country rock there, large supplies of water are in many places obtained by putting down deep bore holes which, meeting underground fissures through which water is passing, afford a passage for the water to the surface.

Conditions prevailing under the Island of Montreal.

Figure 5 also illustrates in a general way, as will be shown, the underground conditions which prevail on the Island of Montreal where the bore holes are put down in heavily bedded limestones and where no constant and definite water-bearing horizons have as yet been reached. A further complexity, however, is introduced in this district by the existence of Mount Royal, the root of an old volcano, which, with the swarm of dykes or walls of igneous rock connected with it, serves to make the course of the underground waters still more devious.

How abundant these walls of impervious rock really are and in what a complicated mesh-work they traverse the limestone strata of the district may be seen in Figure 6 taken from a survey of the floor of the newer portion of the McTavish Street reservoir, made by Dr. B. J. Harrington, many years since, when the reservoir was being enlarged. These dikes are found in almost every quarry and rock-cutting on the island, and may be seen in great numbers on St. Helens island and in the bed of the St. Lawrence at Point St. Charles when the water is low.

A true artesian well must flow.

The term " Artesian well " is properly speaking used only to designate a well which flows, without being pumped, the term being derived from the French province of Artois where wells of this nature, put down in the 12th century, first attracted widespread attention in Europe. Similar wells, however, had long before been known in China, while others in the Libyan desert are believed to be not less than 4,000 years old. In fact there are few parts of the world where the geological conditions are better suited to Artesian boring or where more abundant supplies of water can be had, than over a great part of the North African desert. Under the burning sand here, at a depth of 300-400 feet, there are abundant supplies of water running through pervious sandy strata from the richly watered district of the Soudan to the south, but held down by an impervious limestone cover. It is only necessary to pierce the latter to obtain for the water a passage to the surface, and the French engineers have turned great stretches of the desert into cultivated land by water obtained in this way.

Artesian wells in other countries.

Of recent years the Geological Survey of the United States has devoted a great deal of attention to the subject of Artesian water and immense supplies of excellent quality have been obtained in many parts of the Union to the great benefit of its inhabitants. In New South Wales, Queensland and other parts of Australasia also, search for Artesian water has resulted in securing immense supplies, and throughout the world generally attention has been strongly directed to this source of one of the chief requirements of life.

Enormous yields of the wells.

The force with which the water issues from an Artesian well and the height to which it will rise above the surface, is dependent of course upon the height of the gathering ground above the level of the top of the boring. Other things being equal, the greater the difference in level the higher will the water rise. In the case of certain of the Artesian wells on the plains of Dakota, where the water has its source in the Black Hills and the Rocky Mountains, the water issues with a pressure of as much as 177 lbs. per square inch. One Artesian boring at Woonsocket, South Dakota, throws a 3 inch stream to a height of 97 feet. In many parts of this field the waters are known to run in the porous subjacent beds for several hundred miles before being brought to the surface. There are many Artesian wells in various parts of the world which yield half a million to a million gallons of water every 24 hours, while some of the great Queensland wells yield 2,000,000, 3,000,000 and even 4,000,000 gallons per diem. This yield, however, is exceptional.

Most of the Montreal wells require to be pumped.

In the case of many wells the pressure is barely sufficient to cause an overflow, while again in many instances wells must be pumped in order to bring the water to the surface. Wells of this last class, while often yielding an abundant supply of water, are not properly speaking Artesian wells, and to this class belong almost all the wells in the Island of Montreal, only six of the eighty-nine, above mentioned, being actually flowing wells, although in many of them the water rises to within a few feet of the surface.

The water pressure naturally shows a marked tendency to become lowered when a large number of wells are bored in a limited area, especially when the water is derived from a porous bed of limited thickness. Thus, in London, England, where originally the water rose above the surface in all borings put down on the lower grounds of the valley of the Thames, now, owing to the multitude of deep wells which have been sunk, the inflow of surface water cannot keep pace with the quantity removed by pumping, and consequently the water-level has been lowered to such an extent that it now stands about 100 feet below the surface of the Thames. Another striking instance is afforded by the area on which stands the city of Denver, Colorado. Here, the first Artesian well was sunk in 1883.

Pressure lowered when many wells are sunk in same district.

"The flow yielded by the first well was so large, and the water was of such superior quality for domestic use, that other wells were put down with great rapidity. There are now (1889) in the city and its vicinity about 300 wells. Many of the first wells had sufficient pressure to force the water into tanks, or to the tops of the highest buildings in the city, but as the number of wells was increased the pressure and flow of the older wells began to diminish, and finally in the region where they are most closely grouped they have failed to furnish water without the aid of pumps. Outside the region of closest grouping both pressure and flow have been diminished, but not to so great an extent. Deep wells are still bored at Denver, but not with the expectation of obtaining an Artesian flow.* "

Character of artesian water

Artesian water has comparatively little value unless it be fresh and sweet, but in many cases the water obtained from Artesian borings is saline and not potable. In other cases Artesian waters are very hard owing to a large content of lime salts. This arises from the fact that the waters have, during their underground journeys, passed through beds containing salt, gypsum, limestone or other soluble materials and have taken these into solution. In some cases also the waters have penetrated into the earth's crust to such a depth that they have become heated by increased proximity to the central portion of the earth, and, rising again to the surface, produce warm springs. These, as well as many cold waters, frequently contain mineral matters in solution which are distinctly beneficial and not harmful, and thus the mineral waters, so largely used for medicinal purposes, result.

In the case of the district about Montreal, as will be shown, all these classes of waters have been obtained by deep borings, although the water has not penetrated into the earth's crust in any case to a sufficient depth to be noticeably warm when it rises again to the surface.

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* Evidence of the Director of the United States Geological Survey before the committee of the House of Representatives on Irrigation, Feb. 27th, 1890. Eleventh Annual Report, U. S. Geol Survey, pt. 2, p. 262. Washington 1891.

SKETCH OF THE GEOLOGY OF THE MONTREAL DISTRICT.

Consists of two dissimilar tracts of country.

In the area embraced by the accompanying geological map of the Montreal district, there are two distinct and dissimilar tracts of country, each constituting a well-marked topographic facet or belt; these are the Laurentian plateau to the north-west, composed of very ancient crystalline rocks, and the Palæozoic plain to the south. These two facets—only small parts of which are included in this map—have a wide development in Canada.

Elevations

The Laurentian plateau extends from Labrador south-west to Lake Superior, and thence northward to the Arctic Ocean, and has an area of over 2,000,000 square miles.* The plain bounded on the north by this plateau stretches from the Notre-Dame mountains, in Quebec, to Lake Huron and southward into the United States. The Laurentian plateau is a rolling, comparatively hilly and rugged country. That portion of it embraced within the limits of the accompanying map rises abruptly from the plain, the elevation becoming gradually greater on going to the north. At the north-west corner of the map it has an average elevation of about 600 feet above sea-level, while 15 miles further north the average elevation reaches 1,000 feet, and 25 miles still further north the country frequently attains an elevation of 1900 feet, while some hills rise still higher; the most notable of these is Trembling mountain the summit of which is 2,380 feet above the sea. The valleys are more or less filled with drift and in the hollows are numerous lakes, the abundance of the latter being one of the most characteristic features of the Laurentian highlands.

The Palæozoic plain is flat and thus offers a strong contrast to the topography of the plateau. The average elevation in the vicinity of Montreal is about 100 feet above sea-level, but there is a gentle rise towards the north-west, which gives the plain at its junction with the plateau an elevation of about 300 feet. The whole area is drift-covered and forms farming lands of exceptional fertility.

Mont Calvaire and Mount Royal.

The continuity of the plain, within the area of the map, is broken only by Mont Calvaire at Oka, and by Mount Royal, rising behind the city of Montreal. The former is an outlier of the Laurentian plateau—an ancient island in the Palæozoic sea—and has an area of about 30 square miles, while the latter is the most westerly of a line of old volcanoes and laccolites, known as the Monteregian Hills†, which cut the Palæozoic rocks of the plain. In the following brief description of the geology of the Montreal district only the salient points concerning the different formations will be noted, the reader being referred for more extended descriptions to the reports mentioned in the foot-note.*

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* See A. W. G. Wilson: The Laurentian Peneplain. *Journal of Geology*, October and November, 1903.

† F. D. Adams: The Monteregian Hills; a Canadian Petrographical Province. *Journal of Geology*, April, 1903.

THE LAURENTIAN PLATEAU.

Geological character.

This plateau is composed of a great complex of rocks, mainly of igneous (plutonic) origin, such as granites, syenites, gabbros, etc., but also comprises some of the most ancient sediments of the earth's crust. Since their formation these rocks have suffered great alteration, being now folded, contorted, crushed and recrystallized. The thermodynamic forces have destroyed their original structure, and substituted for it a banded or schistose character. These metamorphic rocks are termed gneisses and schists, the designations being modified to indicate the composition of the particular rock under consideration; for example, granite gneiss, mica schist, amphibolite, etc.

The highly altered sediments folded in with these igneous rocks belong to what is termed the Grenville series. They consists of beds of rusty-weathering gneisses, impure crystalline limestones, garnet rock, amphibolites and quartzites, corresponding respectively to the shales, limestones, calcareous shales and sandstones of unaltered sedimentary strata. This series is very important, not only as representing some of the very earliest sediments on the surface of the earth, but because of the many minerals of economic value which it contains.

Grenville series.

Subsequent to the Grenville period, but still in Laurentian time, there was a great development of igneous activity along the southern edge of the plateau, and great masses of anorthosite were intruded in the above-mentioned series. Portions of these are shown on the accompanying map, at New Glasgow, St. Jérôme and in St. Colomban, respectively. Anorthosite is a gabbro made up almost wholly of Labrador feldspar. A later series of intrusions is represented by the numerous dykes which cut all these older rocks. These dykes are chiefly diabases and are pre-Potsdam in age and are thus quite distinct in character and age from those connected with the intrusions of

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* Geology of Canada, 1863. Chaps. 3, 4, 5, 6, 7, 8, 9, 10 and 13.

R. W. Ells: Report on a Portion of the Province of Quebec comprised in the south-west sheet of the Eastern Townships. Geological Survey of Canada, Vol. VII, 1896; pp. 44-50, 74-75, 85-86.

F. D. Adams: Geology of a Portion of the Laurentian Area lying to the north of the Island of Montreal. Geol. Survey of Canada, 1897; Part J.

Mount Royal. This plateau, composed of crsytalline rocks of Laurentian age, was part of the primitive continent of North America and formed one of the nuclei about which the continent as now seen was built up.

TRE PALÆOZOIC PLAIN.

At the beginning of the Lower Silurian era of Palæozoic time the Laurentian plateau, standing at a certain elevation above the sea which then covered the plain, was acted upon by the various agents of erosion and decay, both sub-aerial and marine. The accumulation of debris derived from the waste of the Laurentian continent was assorted by the waves and deposited in the sea along the flanks of the primitive continent. Thus a series of stratified rocks was laid down on the sea floor, and on these other sediments from the ocean were subsequently deposited, forming what is known as the Lower Silurian or Ordovician system. These rocks underlie the plain.

Palaeozoic formations.

The formations of the Lower Silurian are the following, enumerated in ascending order :—

Potsdam Sandstone.

Calciferous Sand-rock.

Chazy Limestone.

The Trenton Group—consisting of limestones.

Utica Shale.

Lorraine (Hudson River)—consisting of shales and sandstones.

Potsdam Sandstone.

Potsdam sandstone.

The *Potsdam Sandstone* was the first formation laid down on the Archæan floor. It is represented in type by the modern sand and gravel deposits which flank our coasts. Its lowest members are beds of conglomerate, holding pebbles of Laurentian gneisses and quartzites. These beds pass upwards into evenly stratified, fine-grained, and very quartzose sandstones. It is distinctly a shallow water formation and many layers show false bedding, ripple marks, with tracks and burrows of animals which crawled upon the shallow sea bottom or burrowed in the sand. The formation in this district flanks the Laurentian plateau, first as a narrow band, which, broadening out in its southern extension, embraces the old island of Mont Calvaire and extends southward into the counties of Vaudreuil, Soulanges and Beauharnois. Ile Perrot is wholly underlain by the Potsdam and there are small exposures on the Island of Montreal at Ste. Anne de Bellevue, where fine worm burrows and ripple marks are to be seen in the nearly horizontal beds. The thickness of the formation varies from 300 to 700 feet.

Calciferous Sand Rock.

Calciferous.

A slow sinking of the Laurentian plateau was in progress from the beginning of the Potsdam period, and as a consequence, the succeeding formation, the Calciferous, representing deeper water conditions, immediately overlies the Potsdam, the two being united by transitional beds, so that the lower formation insensibly graduates into the upper. Marine life was more abundant during this period, as evidenced by the number of fossils inclosed in the Calciferous. Gastropods (sea snails), Cephalopods (ancient types of devil- or cuttle-fish), and many forms of Brachiopoda found a suitable environment in the calm waters of the Calciferous sea.

The rock itself varies somewhat in character, but usually is a grayish, semi-crystalline dolomite or magnesian limestone, which is generally arenaceous or siliceous and occasionally argillaceous. In many instances it holds geodes of quartz and calcite, and irregular streaks and patches of black chert.

In horizontal distribution it succeeds the Potsdam, forming a second belt along the margin of the old continent, and is well developed in the counties of Terrebonne, Two Mountains, and on the north-west side of Ile Jésus, the west ends of Ile Bizard and the Island of Montreal, and south of Lake St. Louis and in the county of Beauharnois. From surface measurements the thickness of the formation seems to vary from 300 to 450 feet.

Chazy Limestone.

Chazy limestone.

In the Chazy time, with a farther deepening of the sea, the conditions became more truly oceanic, and there was consequently a great development of marine life, particularly of the Brachiopoda. These, through the accumulation of their shells, built up extensive beds of limestone, many of the latter consisting almost wholly of the shells of a single species, Rhynconella plena.

The formation is represented by granular, semi-crystalline light and dark gray limestones, made up in great part of shells and their comminuted fragments. Interstratified with the limestone beds are occasional shaly layers which indicate the influx of muddy waters into the prevailingly clear waters. In geographical distribution the formation appears as a narrow sinuous band following the Calciferous and which broadens out as it crosses the middle of Ile Jésus and the Island of Montreal. From the southwest end of Ile Jésus, another body passes across Ile Bizard and the west end of the Island of Montreal, and thence passing beneath the waters of Lake St. Louis occupies an area extending from Chateauguay and Caughnawaga to the southern limit of the map. The field relations give the Chazy a thickness of about 300 feet.

Trenton Group.

Trenton group.

The Trenton group, into which the Chaz insensibly merges, consists of three divisions which, in ascending order, are known as the Bird's Eye, Black River and Trenton formations. As the Bird's Eye and Black River divisons are not especially well developed in the vicinity of Montreal, no attempt has been made to separate them in mapping and hence the whole group is represented by one colour.

The Trenton is one of the most persistent and conspicuously marked series of strata of the Lower Silurian in North America, and judging from the abundance of the remains of marine invertebrate life this period evidently represents long continued and truly oceanic conditions, the waters being clear and probably warm. In addition to numerous representatives of previously mentioned marine families, Trilobites and Corals flourished, the latter especially giving rise to great beds of limestone.

The rock is usually a granular, semi-crystalline, dark gray limestone, more or less bituminous, and contains a variable amount of argillaceous (clayey) material. In many instances the limestone beds are separated by thin partings of shale, these being thicker and more pronounced at the top of the series where the Trenton passes into the Utica formation.

The Trenton group runs in a rather broad band from L'Assomption to south of the St. Lawrence. It is extensively developed in the vicinity of Montreal, and immediately underlies the city. In the district about Montreal it was supposed by Logan to have a thickness of about 600 feet.

Utica Shale.

Utica shale.

The marine conditions prevailing in the Trenton were succeeded in Utica times by a gradual elevation of the sea bottom, and the clear deep water of the former period became shallow and muddy. This change of conditions was not favourable to the existence of those forms of life which flourished in the Trenton, consequently they, for the most part disappeared, their place being taken by forms of life adapted to cold and muddy waters. The Utica formation consists of thinly laminated black and brownish black shales often bituminous and which are very brittle, usually breaking up where exposed to the weather into small thin fragments. The formation occurs only in the eastern part of the area embraced by the accompanying map, following the course of the River St. Lawrence. On the Island of Montreal it extends from Verdun to Point St. Charles. There is also a small area at the north end of the island. It underlies the harbour of Montreal and forms the south end of St. Helens island. Its maximum thickness is about 300 feet.

Hudson River or Lorraine Shale.

Hudson River shale.

The Utica formation passes upwards into the less bituminous and sandy shales and the thinly bedded sandstones of the Lorraine. The conditions of deposition must have been somewhat similar to those of the Potsdam period, except that the sands were mixed with clay instead of being purely arenaceous.

The Lorraine has a thickness of about 2000 feet and is developed along the extreme eastern margin of the map.

These lower Silurian formations, from the Potsdam to the Lorraine in this area, have been but little disturbed. Over the greater part of the area they either retain their original horizontal position, or dip to the south-east at a low angle, seldom exceeding 5 degrees, The Chazy and Trenton on Ile Jésus and Montreal island, however, display a low anticlinal arch, the axis of which runs north-west from Mount Royal. This is traversed by two others, one on each of the islands, with axes almost at right angles to the main anticline.

Another anticline with an axis running north 23 degrees west is seen in the western portion of the area, the central part or dome of which is occupied by the Archæan outlier of Mont Calvaire. Between Mont Calvaire and the border of the Laurentian plateau, the outcrop of the Potsdam and Calciferous gives to the former the outline of an hour-glass.

The Igneous Intrusions of Mount Royal.

Mount Royal.

During the Devonian or post-Devonian time that part of the Palæozoic plain in the vicinity of Montreal was the scene of great volcanic activity, the present evidences being the line of igneous hills which extend from Shefford to Mount Royal. These hills, greatly reduced in size and representing merely roots of the original volcanoes or in some cases uncovered laccolites, by reason of the flatness of the plain, form striking topographic features, and are locally known as mountains.

Essexite and Nepheline Syenite Intrusions.

The igneous mass of Mount Royal occupies an area of about one and a half square miles, and is surrounded by the Trenton limestone, through which it has broken, and which by it has been in many places altered to marble. The main part of the mountain is composed of Essexite, a plutonic rock composed essentially of plagioclase feldspar, augite and hornblende, with a little nepheline. Olivine is in some places present as an accessory constituent. This Essexite was subsequently cut through by a later intrusion consisting of Nepheline syenite, a rock which is genetically related to the former and which consists essentially of orthoclase feldspar, nepheline and hornblende. It represents a more acid phase of the original magma. The Nepheline syenite appears as a comparatively broad band along part of the north-west flank of the mountain. This intrusion is quarried at Outremont for road metal and is of particular interest in that it has furnished a number of rare minerals, that most recently discovered being Native Arsenic*

Dykes and sills.

Associated with these intrusions is a great swarm of dykes, that is to say, more or less steeply inclined or vertical walls of igneous rock, which cut both the Essexite, Nepheline syenite and the surrounding stratified rocks in all directions. There are also numerous sills or sheets of the same, intercalated between the beds of the stratified rocks. These dykes and sills consist of a complete series of those rarer varieties of dyke rocks which belong to the Nepheline syenite—Essexite magma and which are known as Bostonite, Camptonite, Alnoite, Tinguaite, etc. They are related genetically to the former intrusives and represent the closing stage of the volcanic action. The dykes may be seen in almost all large exposures of rock in the vicinity of Montreal, as for instance in Mount Royal Park, the Corporation Quarry at Outremont, the Mile End Quarry, or on St. Helens island.

The most westerly representative of this series of igneous rocks, connected with the volcanic centre of Mount Royal, is found on the south east flank of Mont Calvaire. Its relations to the mass are not well seen, but it is either a broad dyke or a sill which cuts through the massive crystalline limestone of the Laurentian on the north and a body of pegmatite on the south; the intrusion in each case running into the wall-rock and holding an immense number of included fragments. The rock bears a marked resemblance to that of the well-known occurrence of alnoite which is found as a dyke cutting the Potsdam sandstone at the bottom of the Ottawa river opposite Ste. Anne de Bellevue.*

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*Evans, N.N.: Native Arsenic from Montreal. Amer. Jour. of Science. Feb. 1903.

In order to show how numerous these dykes are in certain places about Montreal and the complicated manner in which they cut one another, there is presented in Figure 6, a small scale map af an area now covered by the waters of the Montreal Reservoir on McTavish street, which was surveyed by Dr. B. J. Harrington some thirty years ago during the construction of the reservoir. As will be seen there are here within an area about 200 yards in length by 100 yards in width, not less than 46 dykes, belonging to some seven different series, each series cutting those older than itself.

Their influence on underground waters.

These dykes in their underground extension, forming impervious walls crossing the fissures through which water runs, certainly have a very important influence locally in determining the courses taken by the subterranean waters.

At several localities about the Island of Montreal, a peculiar breccia occurs which is evidently connected with the Mount Royal intrusion. It is found on St. Helens island and Ile Ronde, Ile Bizard, at White Horse rapids, Rivière des Prairies, and on the east flank of Mont Calvaire, apparently overlying respectively the Utica, Chazy, Trenton and Potsdam formations. It also occurs in fissures at Pointe Claire in the Chazy, and at McGill College in the Trenton. Its best development is on St. Helens island. The breccia is massive and unstratified and consists of angular and rounded fragments of gneiss, quartzite, limestone, red and gray sandstone, shale and hornstone, imbedded in a dark gray matrix of impure dolomite.

These fragments represent a vertical range in the geological time-scale extending from Laurentian to Lower Devonian, for two large masses of limestone included in the breccia are respectively Lower Helderberg (Upper Silurian) and Lower Devonian in age. The former corresponds chronologically to the Upper Pentamerus zone of Eastern New York, and the latter to the Oriskany formation as exposed in Western Ontario and Virginia as shown by a detailed palæontological study of the occurrences recently made by Dr. H. S. Williams. It is believed that in these areas of breccia are preserved the last surviving remnants of the ejectamenta of the volcano of Mount Royal, and that

Volcanic ejectamenta on St. Helens island.

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*F. D. Adams : On a Melilite-bearing Rock (Alnoite) from Ste Anne de Bellevue, near Montreal, Canada. *Amer. Jour. Sci.*, April, 1892.

on St. Helens island is of especial interest as presenting conclusive evidences of the extension of the Upper Silurian andDevonian seas as far north as Montreal.* The breccia is cut by several dykes, which proves that it was formed before the volcanic activity had entirely ceased.

Pleistocene.

Pleistocene deposits.

Between the Devonian and the Pleistocene a great gap exists here in the geological record, the upper part of the Palaeozoic and the whole of the Mesozoic and Tertiary being unrepresented.

During Pleistocene time, however, it is known that an Arctic climate prevailed and that the area was covered by the great ice sheet known as the Laurentian glacier, which gave rise to certain deposits characteristic of glacial action. These drift deposits consist of clays, sands and gravels, the lowest member being the boulder clay ("hard-pan") composed of glaciated boulders embedded in a fine clay or rock-flour. This is very compact and resists erosion as readily as many of the old stratified rocks. The upper members of the drift, which are stratified clays, sands and gravels, were formed during a post-glacial submergence, which followed the retreat of the ice sheet. In the vicinity of Montreal they are known as the the Leda clay and Saxicava sands and gravels. From the abundant fossil remains (shells) in these marine deposits, it is inferred that the climate was sub-arctic, as closely related species (in many cases identical) are now found living off the coast of Labrador.

This marine submergence was very widespread, the sea level reaching a height of at least 625 feet on Mount Royal and covering the entire plain.

Terraces.

As the land slowly rose again, the sea retreated, and marked by a terrace each level at which it remained stationary for a time. In this way the series of terraces, encircling Mount Royal mark the successive stages of emergence from the Pleistocene sea. These terraces are well developed at Montreal between the Mountain and harbour, the most prominent ones being those on which Sherbrooke street and St. Catherine street are located, and which form striking features in the landscape along the banks of the St. Lawrence both to the north and south of the city.

The accompanying table presents the chief characteristics of the above named formations in tabular form.

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* A. W. Nolan & J. D. Dixon : The Geology of St. Helen's island. Can., Record of Science, Vol. IX, No. 1, p. 53 (1903).

SYNOPTICAL TABLE OF GEOLOGICAL FORMATIONS ABOUT MONTREAL, CANADA.

By Henry M. Ami, and Frank D. Adams.

System.	Formation.	Character of Strata, etc.	Characteristic Fossils.	Thickness as determined from surface outcrops.	Localities.
POST-TERTIARY OR QUATERNARY.	Recent. (Sorel.)	Alluvium, river and lake deposits, silts, shell-marl deposits.	Goniobasis livescens, Planorbis parvus, P. trivolvis, P. bicarinatus, Unio complanatus, U. rectus.	Varies from a few inches to 30 and 40 ft.	Pte. aux Trembles, Boucherville Islands, shores of St. Lawrence and submerged portions of islands adjoining.
	Champlain. Saxicava.	Light yellow or ferruginous sands.	Saxicava rugosa, Linnæus. Macoma fragilis, Fabricius.	From a few ins. to several ft.	St. Louis and Mile End Quarries, the Tanneries, terraces along Craig street, Beaver Hall Hill, Sherbrooke and St. Denis sts. at different elevations.
	Leda Clay.	Bluish-gray, fine grained plastic or stiff clays and muds, brown and dark coloured.	Yoldia limatula; Portlandia arctica; Mytilus edulis, Linnætus.	From a few ins. to 50 ft.	
		Glacial and boulder clays, 'till', clay and sand and rock fragments derived from older formations.	None detected as yet.	From a few inches to upwards of 100 ft.	Along Lachine canal, Hochelaga, also underlying the Leda clay almost everywhere.
POST-DEVONIAN	Intrusives.	Nepheline Syenite, Essexite, Camptinite, Tinguaite, Alnoite, etc., Breccias.		Forming conspicuous masses breaking through the Ordovician plain	Mount Royal, Montarville, Rougemont, Beloeil, Mt. Johnson, St. Helens Island agglomerates.

DEVONIAN.	ORISKANY.	Fragments of light gray impure fossiliferous limestone.	Cyrtina rostrata, Spirifer arenosus Metaplasia pyxidata	Not ascertained. Isolated patches and fragments.	St. Helens island, as fragments in the breccias or volcanic agglomerates of Post Devonian age.
SILURIAN.	LOWER HELDERBERG.	Light gray impure subcrystalline and altered limestone—as small outliers.	Camarotœchia ventricosa, Gypidula pseudogaleatus, Spirifer concinnus, Rensselæria mutabilis. Leptæna rhomboidalis; Strophodonta varistriata; Strophonella punctulifera; Pentamerus (Sieberella) galeatus, Atrypa reticularis, Platystoma depressum.	Not ascertained. Isolated patches.	St. Helens island, as fragments in the breccias. Belœil mountain.
ORDOVICIAN.	LORRAINE.	Black or dark brown and buff weathering shales and arenaceous beds and mudstones. Fossiliferous.	Favistella stellata, Orthograptus quadrimucronatus, Zygospira Headi, Pterinea demissa, Byssonychia radiata, Clidophorus planulatus, Orthodesma parallelum. Protowarthia cancellata, Cyrtolites ornatus.	From a few feet to 2000 feet.	Chambly; St. Lambert, Rivière des Hurons; L. A. 5, Con. 3 Chambly Canton; Rougemont, Belœil stat'n.
	UTICA.	Dark brown and black bituminous shales or pyroschists with impure limestone bands at base.	Leptograptus flaccidus, Leptobolus insignis, Schizocrania filosa, Cornulites immaturum, Endoceras proteriforme, v. tenuistriatum, Triarthrus Becki, Trocholites ammonius.	Between 100 and 300 feet.	South end of St. Helens island; St. Lawrence Riv. bed and shores near Lachine Hydraulic Co.'s works; Victoria bridge, below piers.

SYNOPTICAL TABLE OF GEOLOGICAL FORMATIONS ABOUT MONTREAL, CANADA—*Continued.*

By Henry M. Ami, and Frank D. Adams.

System.	Formation.	Character of Strata, etc.	Characteristic Fossils.	Thickness as determined from surface outcrops.	Localities.
ORDOVICIAN.	Trenton.	Dark gray impure fossiliferous limestones and shales extensively quarried for building purposes. At times semi crystalline.	Glyptocystites Logani, Heterocrinus tenuis, Pachydictya acuta, Phylloporina Trentonensis, Prasopora Selwyni, Plectambonites sericea, Trematis Montrealensis, Dalmanella testudinaria, Lingula riciniformis Parastrophia hemiplicata, Rafinesquina alternata, Platystrophia lynx, Cyclonema Montrealense, Trochonema umbilicatum, Conularia Trentonensis, Trinucleus concentricus, Isotelus gigas, Calymene senaria.	About 500 feet.	Montreal, Hochelaga, Pte. aux Trembles, Lachine, St. Louis and Mile End quarries.
	Black River.	Light gray weathering, dark gray and black impure fossiliferous limestones. Building stone.	Tetradium fibratum, Columnaria Halli, Stromatocerium rugosum, Helicotoma planulata, Cyrtodonta Huronensis Bathyurus extans.	About 75 feet.	Pointe Claire quarries, St. Vincent de Paul.
	Chazy.	Light and dark gray semi-crystalline impure fossiliferous limestone--useful for building purposes.	Bolboporites Americanus, Malocystites Murchisoni, Blastoidocrinus carcharisedens, Camarotœchia plena, Hebertella borealis, Dinorthis platys, Bathyurus Angelini.	Between 150 and 300 feet.	Back River north of Mt. Royal, Sault au Récollet, St. Martin, Bord à Plouffe, Terrebonne Caughnawaga.
	Calciferous.	Dark gray buff and yellow weathering impure earthy and semi-crystalline limestones, for the most part magne-	Orthisina grandæva, Billings, Pluroto-maria Calcifera B. P. Canadensis, B. Hormotoma Anna, B.. Metoptoma simplex, B., Orthoceras Lamarcki, B., Amphion Salteri, B., Bathyurus	Between 300 and 450 feet.	Ste. Anne quarries at railway station and east of village, northwest corner of Ile Jésus, Ile Bi-

		sian, and holding numerous crystals filling cavities. Lower measures arenaceous.	Cybele B., Ribeiria calcifera, B., Leperditia Anna B.		zard, St. Eustache, Chateauguay river, above Chateauguay village.
	POTSDAM.	Light yellow and rusty weathering sandstones and conglomerates occasionally present at the base and along certain divisional planes of stratification.	Scolithus Canadensis, Bill., Protichnites multinotatus, Owen ; P. lineatus, Owen., P. octonotatus, Owen, P. septem-notatus, Owen.	Between 200 and 700 feet.	Western extremity of Island of Montreal at Ste. Anne, Ile Perrot, Beauharnois, Vaudreuil, etc
LAURENTIAN.	MORIN INTRUSIVES : "NORIAN."	Anorthosites, foliated gabbros.		Large body having area of 990 square miles & smaller ones several penetrating older masses.	St. Agathe, St. Adèle, Kilkenny, Morin, Lakefield area, St. Jérôme.
	GRENVILLE SERIES.	Crystalline limestones, gneisses and quartzites	None.	Thickness of crystalline limestone and quartzite bands varys constantly.	District south of Rawdon ; St. Sauveur district.
	Lower Laurentian. (FUNDAMENTAL GNEISS).	Foliated gneisses, granitoid gneiss, augen-gneiss.	None.	Forming masses of igneous origin with indefinite thickness.	Oka, St. Colomban, St. Jérôme, St. Canut.

CLASSIFIED LIST AND DESCRIPTION OF THE WELLS WHICH HAVE BEEN PUT DOWN ON THE ISLAND OF MONTREAL.

Report includes all wells put down prior to close of the year 1903.

In this section a list and description is given of all the borings, so far as can be ascertained, which had been put down on the Island of Montreal, up to the close of the year 1903. As will be seen, they are eighty-nine in number. It is just possible that some others may have been put down whose existence has escaped the attention of the writers and which are not here recorded. If so, these are very few in number, as the search for these wells has been a thorough one and the list is believed to be complete.

In many cases the information obtained covering individual wells is very meagre, and in no case is it as full as could be desired. In every case, however, all the information which it was possible to obtain has been presented.

The borings are classed under three heads: those yielding (1) Potable Water, those giving (2) Sulphuretted or Saline Water, and (3) Dry Wells. This classification is more or less arbitrary. Some waters are slightly sulphuretted and lose their odour on standing for a time, while others are highly charged with sulphuretted hydrogen. It is difficult, therefore, especially in the absence of detailed chemical analysis, in many cases to determine in which class a water should be placed. The character of a water, however, cannot be seriously misjudged, even if it happens to have been placed in Class I, when it belongs rather to Class II, or *vice versa,* since the description will serve to show its character so far as this is known.

Eighty-nine wells,

Again, the term "dry well" is one which may be defined in different ways. None of these wells were absolutely dry. In all cases enough water oozed into the hole to allow the boring to be readily carried on. Such borings, however, although wet, yield no supplies of water which could be pumped. Other wells again would yield two or three thousand gallons a day. This yield may be sufficient for the very moderate needs of a farmer, for instance, but it would be useless in the case of a large manufacturing establishment. In fact, a well which will not yield over 5,000 gallons per diem is considered by the well drillers to be a "dry well."

Classification of wells.

When a well is drilled its capacity is determined by pumping it for several hours and thus ascertaining the amount of water which it will yield. The values given as 'capacity per diem in gallons' in the accompanying tables, are arrived at by taking the number of gallons thus pumped per hour and multiplying by twenty four. The capacity thus stated may therefore in some cases be in excess of the actual per diem capacity of the well, but the amount of water stated by the drillers to have been actually pumped in the trials made on the completion of the well is given in the text in each case where a trial was made—and may be there ascertained.

Method of determining the yield.

The capacity of many of the wells has not, however, been actually determined. In certain cases if the well yielded the small amount of water required, this was considered to be quite satisfactory and no test was made as to the full yielding power or capacity of the well. In these cases it is impossible to apply the well-drillers' definition. It has therefore been considered best to use the term 'dry well' in the sense of a well which would not afford any supply of water, but in calculating the proportion of wells which give adequate supplies of water as compared with the total number of wells put down, an adequate supply has been considered to be 5,000 gallons per diem. Under each heading the wells have been arranged in alphabetical order—for convenience of reference—quite independent of their location on the island.

On the accompanying map of the City of Montreal and vicinity the location of each well is indicated by a coloured dot, the colour employed in each case showing whether the water is Potable, Sulphuretted or Saline, or whether the boring was a Dry one.

Several sets of wells are on this map connected by dotted lines, and the sections of the wells of each set are plotted on the accompanying sheet of diagrams (figures 7 to 10), thus showing clearly the comparative character of groups of adjacent wells.

Definitions of terms used.

In the tabulated list the wells of all three classes are put together and arranged in alphabetical order and the chief facts concerning them are given. In this list the potable waters are marked "good" when they are known to be potable, but when nothing further is known concerning their nature. When their character is known more definitely they are marked "soft" or "hard". The saline or sulphuretted waters are entered as such.

Tabulated List of the Artesian and other

No.	Name of Owner.	Location.	Depth in ft.	Diameter of hole in inches.
1	R. B. Angus	Ste. Anne de Bellevue	222	4½
2	Armstrong & Cook	Montreal West	500	....
3	Belding, Paul & Co	On Canal, near Seigneur St Bridge.	548	6
4	Bushnell Oil Co	Ville St. Louis	305	4
5	C. S. Campbell	Dorval	480	4¾
6	Canada Brewing Co	218 DeLorimier Ave	580	....
7	The Canada Malting Co	St. Henri (lot 104781)	678	6 & 4¾
8	" "	" "	506	....
9	" "	"Abattoir Site", near St. Henri	1281	4¾
10	The Canada Sugar Refining Co	150 Montmorency St	312	....
11	Canadian Pacific Railway	Hochelaga	539	8 & 6
12	" " "	"	557	8 & 6
13	" " "	Outremont	410	5½ & 4
14	Convent of the Precious Blood	Notre-Dame de Grâce	296	....
15	M. Cousineau	St. Laurent	128	....
16	Dr R. Craik	Petite Côte, lot 192	305	4
17	Mr. Curran's Farm	Between St. Laurent & Back River	260	6
18	The Thomas Davidson Manufacturing Co	187 Delisle Ave., Ste. Cunégonde	150	6
19	Dawes & Co	Lachine	1003	....
20	W. B. Dickson	Longue Pointe, lot 21	170	....
21	The Dominion Wadding Co.	Cor. Williams & Vinet Ste. Cunégonde	175	6
22	William Dow & Co	186-188 Colbourne St	360	4¾
23	" "	" "	420	4¾
24	" "	" "	430	4¾
25	" "	Same property—cor. of Inspector St.	890	4¾
26	Alex. Drummond	Petite Côte	500	....
27	Sir. G. A. Drummond	Beaconsfield	425	....
28	J. N. Drummond	Petite Côte, lot 195	223	....
29	H. A. Ekers	Petite Côte, lot 208	325	....
30	Ekers' Brewery	409 St. Lawrence St	600	....
31	Excelsior Woollen Mills	967 Ontario St	812	6 & 4
32	Excelsior Woollen Mills	967 Ontario St	754	10 & 6
33	Excelsior Woollen Mills	967 Ontario St	300	....
34	The Fenlin Leather Co	141 Frontenac St	1025	....
35	M. Galibert	929 St. Catherine St	454	4
36	H. Gatehouse	808-810 Dorchester St	750	....
37	Globe Woollen Mills	219 Delorimier St	410	....
38	The Gould Cold Storage Co.	Grey Nun & William Sts	1301	....
39	" "	" "	500	....
40	A. Goyer	Frontenac St	375	4¾
41	F. Goyer	Côte des Neiges	250	4¾
42	M. Grosboyau	1675 Papineau ave	350	....
43	Chas. Gurd	39 Jurors St	512	....
44	Mr. Hampson	Longue Pointe, lot 40	502	....
45	A. Hobbs	Outremont (back of C.P.R. Round House)	240	6
46	Edward Hughes	Côte St. Michel	75	....

Deep Wells on the Island of Montreal.

Capacity per diem in gallons.	Water level in feet.	Character of water.	Remarks.
48,000	-12	Good	
10,000	-100	Hard, slightly-sulphurus.	Rock 50 feet from surface.
91,000	-10	Hard	Rock 64 feet from surface.
1,000+	-20to-30	Hard, slightly-sulphurus.	Rock at surface.
12,000	-20	Good	
24,000	-28	Good	Rock 50 feet from surface.
12,000	-6	Good	Water was obtained at 300 feet. Rock 32 feet from surface.
16,800	30	Good	Rock 18 feet from surface.
18,000	-10	Highly saline	Water at 350 feet and no further supplies below. Rock 30 feet from surface.
120,000	-18	Good	Rock 70 feet from surface.
240,000	-6	Good	Rock 12 feet from surface.
120,000	-8	Good	Rock 13 feet from surface.
192,000	-8	Hard & sulphurous	Rock 25 feet from surface.
36,000	-20	Good	Rock 42 feet from surface.
abundant	+7	Rather hard	Rock 40 feet from surface.
120,000	-10	Soft	
24,000	-6	Pure	Rock 16 feet from surface.
72,000+	-8	Hard	Rock 50 feet from surface.
abundant	-10	Saline	
....	-13	Saline & sulphurous.	Rock 100 feet from surface.
abundant	-8	Pure	Water at 160 ft. Rock 90 feet from surface.
24,000	-50	Not sulphurous	
to small to be of any value	-40	....	
60,000	-30	Slightly sulphurous.	
hardly any water			
8,400	-50	....	Rock 5 feet from surface.
36,000	-10	Hard	Rock 10 feet from surface.
24,000	-25	Soft, slightly-sulphurus.	
14,000	-33	Rather hard	
25,000	-10	Good	Rock 70 feet from surface.
5,000	-100	Good	Water obtained at about 600 feet.
86,000	-20	....	Rock 35 ft. from surface. Some water at 500 ft.; further supply at 740 feet.
no water	....	....	
too small to be of any value (4800)	....	....	Rock 60 feet from surface.
25,000	-5	Good	Rock 56 feet from surface.
20,000	-30	Good	Rock 46 feet from surface.
65,000	-10	Hard	Rock 35 feet from surface.
10,000	-40	Good	Rock 73 feet from surface. All the water obtained was struck at 360 feet.
none		....	
9,000	-10	Soft	Rock 30 feet from surface.
72,000	-10	Very hard	Rock 25 feet from surface.
abundant	-12	Soft	Rock at surface.
800 without pumping	0	Sulphurous	Water at 440 feet and at 512 feet, 4000 gals. can be pumped.
....	....	Saline & sulphurous.	
48,000	0	Good	Rock 5 feet from surface.
19,000	-20	Soft	Rock at surface.

Tabulated List of the Artesian and other

No.	Name of Owner.	Location.	Depth in feet	Diameter of hol in inches.
47	Laing & Sons	Cor. St. Catherine & Parthenais Sts	325	....
48	Laurentian Baths	208 Craig St	280	6 & 4¾
49	Laurie Engine Company	1020 St. Catherine St	300	6 & 4¾
50	Laurie Engine Company	1012 St. Catherine St	700	....
51	Longue Pointe Asylum	Longue Pointe	2000	....
52	Lovell & Christmas	63 William St	612	6
53	A. Martin	Lachine, lot 1010	740	6
54	A. S. & W. S. Masterman	2082 Notre Dame St	800	....
55	Mrs. J. McIntosh	Côte St. Michel	120	....
56	J. H. R. Molson & Bros	1006 Notre Dame St	674	8½ & 4¾
57	Montreal Brewing Co	1334 Notre Dame St	502	4¾
58	Mount Royal Cemetery	Near Crematory	354	4¾
59	Montreal Cold Storage Co	610 St. Paul St	1020	....
60	The Montreal Gas Co	Hochelaga	1850	....
61	" "	"	2550	....
62	" "	Ottawa St	1050	....
63	Montreal Hunt Club	Outremont	226	6
64	The Montreal Locomotive & Machine Co	Longue Pointe	514	....
65	Montreal Milling Co	Park Ave., Outremont	345	5
66	Mount Royal Park	"Park Well"	66	4
67	Montreal Weaving Co	595 Clarke St	420	....
68	G. Nantel	Côte des Neiges	600	....
69	Outremont Milling Co	Outremont	335	4
70	Judge Pagnuelo	Pagnuelo Ave	700	....
71	Mrs. Quiggley	Longue Pointe	100	....
72	A. Ramsay	Inspector St	800	....
73	A. Ramsay	Westmount	880	....
74	M. Rheaume	Carrière St	300	....
75	Rowan Brothers	618 Beaudry St	600	....
76	The Royal Golf Club	Dixie	450	....
77	The Salvador Brewing Co	617 St. Paul St	550	4½
78	Sault au Recollet College	Back River	490	6
79	Shawinigan Water & Power Co	Maisonneuve	1017	....
80	Sisters of Providence	Notre-Dame de Grâce	320	4½
81	Stanley Dry Plate Co	613 Lagauchetière St	1300	4¾
82	St. Laurent Convent	St. Laurent	250	....
83	St. Laurent College	"	487	....
84	Mr. Stewart	Petite Côte, lot 195	223	....
85	T. A. Trenholme	Côte St. Pierre, lot 141	185	....
86	T. A. Trenholme	Thorne Hill, Côte St. Pierre	175	....
87	Turkish Baths	140 Ste-Monique St	1550	....
88	Viau et Frères	Maisonneuve	1500	....
89	The Wire & Cable Co	233-241 Guy St	1055	6 & 4¾

Deep Wells on the Island of Montreal—*Concluded.*

Capacity per diem in gallons.	Water level in feet.	Character of Water.	Remarks.
36,000	-30	Hard	Rock 56 feet from surface.
40,000	+20	Soft	Rock 60 feet from surface.
72,000	-15	Hard ; faint iron taste.	Water at 150 ft. Too hard for boilers.
no water	....	....	
9,600	....	Good	Rock 4 ft from surface. All water obtained was struck at 300 ft.
60,000	-30	Slightly sulphurous.	Rock 62 feet from surface.
2,400	-11	Very hard	Rock 65 ft. from surface. Water at 460 ft., associated with gas.
72,000	-10	Sulphurous & slightly saline.	Water at 750 ft. Rock 68 ft. from surface.
14,000	-5	Soft, slight iron & sulphur taste.	
112,800	-24	Saline	Rock 83 ft. from surface. Water at 420 ft.
126,000	-36	Hard	Rock 80 ft. from surface.
36,000	-25	Good	Started on rock surface.
....	0	Sulphurous	Pocket of gas struck. Rock 60 ft. from surf.
none	....	....	
none	....	....	
no water	....	....	Rock 90 ft. from surface.
36,000	-10	Good	Started on rock.
29,000	-25	Somewhat sulph.	Rock 27 ft. from surface.
40,800	-25	Very hard	Rock at surface.
12,000	0	Good	Rock 4 ft. from surface.
12,000	-125	Soft	Rock 5 ft. from surface.
abundant	-10	Good	Rock 5 ft. from surface.
43,000	-25	Very hard	
7,000 (about)	....	....	
4,800	-9	Rather hard	Rock 90 ft. from surface.
48,000 (abo't)	-14	Hard.	
15,000	-18	Rather hard	Water was struck at 700 ft.
24,000	0	Rather hard	Rock 10 ft. from surface.
120,000	-60	Good	Rock 70 ft. from surface. Used for ærated [waters.
28,800	-15	Good	Rock 37 ft. from surface.
too small to be of use. (8,000	....	....	Rock 62 ft. from surface.
12,000	-30	Soft	Rock 35 ft. from surface. Hard water struck 100 ft. from surface. (See Description.)
too small to be of any val. (4,800)	....	....	Rock 26 ft. from surface.
48,000	....	Good	Rock 22 ft. from surface.
8,400	-30	Good	Rock 40 ft. from surface.
abundant	0	....	
10,000	-13	Soft & slightly sulphurous	Rock 31 ft. from surface.
10,000	-25	Soft & slightly sulphurous	
6,000	-25	Good	Rock 100 ft. from surface.
abundant	....	Pure	Rock 75 ft. from surface.
4,000 to 5,000	+6	Soft & slightly sulphurous	Rock 50 ft. from surface.
5,000	÷10	Saline & sulphur.	Rock 90 ft. from surface. Good water at 450 ft.; sulphurous water at 1190 ft.
72,000	rises to surface	Hard	Rock 57 ft. from surface. Most of the water obtained at 960 ft. None found lower.

WELLS YIELDING POTABLE WATERS.

Wells yielding Potable waters.

1.—R. B. Angus, Esq.—St. Anne de Bellevue.

This well is 222 feet deep. It has a diameter of 4½ inches and yields 48 000 gallons a day, the water rising to within 12 feet of the surface. The water is said to be of good quality.

2.—Messrs Armstrong and Cook—Cadastral No. 140 Subdivision lot 293 Montreal West.

In boring this well water was struck at 350 feet, the flow increasing in quantity with depth. At 500 feet boring operations were discontinued.

Fifty feet of clays and gravels were first penetrated then 25 feet of a shaly rock possibly an outlier of the Utica. The remainder is a limestone of uniform hardness, and which gave sufficient water to keep the drill working easily.

In November 1893, the water was 50 feet below the surface after having been pumped from a depth of 100 feet for 10 hours. In December 1894, the water stood at the 100 foot level after a rest of 6 hours, the pump then being 350 feet from the surface. The water is of good quality, with "traces of iron and sulphur," 10,000 gallons per diem have been pumped. (*See figure 9*).

Messrs. Belding, Paul & Co's well.

3.—Messrs Belding, Paul and Company—On the canal near the Seigneur Street Bridge.

The well is 548 feet deep. It is 6 inches in diameter and yields 91,000 gallons per diem. The water rises to within 10 feet of the surface and is hard. The rock was encountered 64 feet from the surface.

The following are the results of an analysis of the water which was made for the company in February 1903:

	Parts per million.	Grains per Imp. gallon.
Calcium Carbonate	47	3.29
Magnesium "	90	6.30
Sodium "	35	2.45
" Sulphate	17	1.19
" Phosphate	17	1.19
" Chloride	90	6.30
Silica	10	.70
Organic Matter	80	5.60
	386	27.02

4.—The Bushnell Oil Company—Ville St. Louis.

The well is 305 feet deep. It is in the solid rock and the diameter is 4 inches. The water level is from 20 to 30 feet below the surface and is lowered somewhat on pumping. The water is rather hard, slightly sulphurous, and holds a small amount of suspended clayey material. One thousand gallons are pumped daily but the maximum capacity is much greater, (*See figure 8*).

5. C. S. Campbell Esq., Dorval.

This well is 480 feet deep and yields 500 gallons of water per hour. The hole is $4\frac{3}{4}$ inches in diameter. The water is of good quality and rises to within twenty feet of the surface.

6.—The Canadian Brewing Co., 218 Delorimier avenue, Cadastral number Lot 502 St. Mary's ward.

The Canadian Brewery Company's well.

In boring this well, water was struck at a depth of 580 feet. Before rock was reached the drill went through 50 feet of drift, 35 feet of which was "hard-pan."

The water level is 28 feet below the surface. Present requirements only necessitate the pumping of 5,000 gallons per diem, although the tested capacity is at least 24,000 gallons.

The following partial analysis of the water was made by Mr. Baker-Edwards on Oct. 20. 1890. The results are stated in grains per Imperial gallon :

Sodium Bicarbonate	38.00
Sulphur as H_2S or sulphides—	not determined.
Sulphur as SO_4	3.36
Chlorine as NaCl	2.705
Nitrogen as nitrates	0.004
Nitrogen as nitrites	none
Free and Saline Ammonia	0.0025
Albumenoid Ammonia	0.0033
Organic Carbon	none
Hardness	4.2° (Clarke's)

7 and 8.—The Canada Malting Company, St. Henri, Lot 104781, near Lachine canal.

Two wells were sunk on this property a short distance from one another. The first of these is 6 inches in diameter down to a depth of 36 feet, the diameter being then reduced to $4\frac{3}{4}$ inches. In it water was obtained at a depth of 300 feet and rose to within six feet of the surface, the well yielding 500 gallons per hour. The water is stated to be of good quality but has not as yet been analyzed. The solid rock was reached 32 feet from the surface. After striking water at a depth of 300 feet, the boring was continued to a depth of 678 feet, without any appraciable increase in the quantity of water being observed.

The second well was sunk to a depth of 506 feet and yields 700 gallons per hour. The rock was reached at a distance of 18 feet from the surface and the water, which was of good quality, rose to within thirty feet of the surface.

9.—The Canada Malting Company—C.P.R. property, "Abattoir Site," near St. Henri.

In this well, highly saline water was struck at 350 feet and rose to within ten feet of the surface. The well yielded 750 gallons per hour. Boring was then continued to a depth of 1281 feet, when, no additional supply of water being obtained, operations were discontinued. The hole is 4¾ inches in diameter and the rock was reached at a depth of 31 feet from the surface.

The Canada Sugar Refining Company's well.

10.—Canada Sugar Refining Company—150 Montmorency street. This well is 312 feet deep and yields 5,000 gallons an hour. The water rises to within 18 feet of the surface, and is of good quality. The drift here is very thick, the solid rock lying 70 feet below the surface.

The following is an analysis of the water by the chemist of the company, the results being given in grains to the Imperial gallon:

Mineral solids	10.78
Organic do	4.57
	15·35

The mineral solids are as follows:—

Calcium Bicarbonate	4.521
Magnesium do	160
Sodium do	1.330
do Sulphate	1.049
do Chloride	3.720
	10.780

Total Hardness	12.40
Temporary Hardness	1.60
Permanent do	10.80

11 and 12.—Canadian Pacific Railway Work Shops—Hochelaga.

The Canadian Pacific Railway Company's well at Hochelaga.

Two wells were sunk on this property, the first to a depth of 539 feet and the second to a depth of 557 feet. The former yields 10,000 gallons an hour, the water rising to within 6 feet of the surface. The second yields 5,000 gallons an hour, the water rising to within 8 feet of the surface. Both wells start with a diameter of 8 inches, which is subsequently reduced to 6 inches. The rock is 12 and 13 feet from the surface respectively in the case of the two wells. The water is said to be of excellent quality,

The water from one of these wells collected on February 6, 1903, shortly after the wells were bored, was analysed by Mr. Milton L. Hersey with the following results, stated in grains per Imperial gallon :

Calcium Carbonate	·43
do Bicarbonate	·00
Magnesium Carbonate	·31
Sodium Carbonate	18·00
do Bicarbonate	·00
do Sulphate	8·20
do Chloride	·00
Potassium Chloride	·00
Calcium Chloride	1·17
Silica	·00
Loss on ignition	3·67
Total solids	31·78

14.—Convent of the Sisters of the Precious Blood—Notre-Dame de Grâce.

This well was sunk to a depth of 296 feet. Water was obtained, the well yielding 1,500 gallons an hour. The water rose to within 20 feet of the surface and is said to be of good quality. The solid rock was reached at 42 feet from the surface.

15.—M. Cousineau, Esq.—Lot 251, St. Laurent.

This well is interesting in that it is one of the few flowing ones of the district, the water rising to a height of 7 feet above the surface of the ground. The well is 128 feet deep, 40 feet in clay, and 88 feet in limestone; the water is pure and of medium hardness. (*See figure 9.*)

Dr. Craik's well.

16.—Dr. Robert Craik—Lot 192 Petite Côte.

In boring of this well, water was struck first at 250 feet, but not in sufficient quantity to keep the drill wet. At 305 feet however additional water was obtained which rose to within 10 feet of the surface.

The water-bearing stratum is shaly in character and the water was at first impure and sulphurous, but these qualities disappeared on continued pumping giving a pure, soft water. No analysis was made beyond a few qualitative tests which confirmed the excellent quality of the water.

In order to test the capacity of the well an engine was used which pumped 5,000 gallons per hour without lowering the water level more than 20 feet below the normal position. A windmill with a six inch stroke is now used; the pump is down 80 feet, while the piping (4 inch), continues 30 feet below the pump. (*See figure 10.*)

17.—Mr. Curran's farm.

The well is situated about half way between Montreal and Back river, about one mile east of the Hotel. It was sunk to a depth of 260 feet and yields 1,000 gallons an hour. The water rises to within 6 feet of the surface. The hole is 6 inches in diameter, and the solid rock was met with 16 feet from the surface.

The Thomas Davidson Manufacturing Co's well.

18.—The Thomas Davidson Manufacturing Company—187 Delisle street, Ste. Cunégonde.

Water was obtained at a depth of 150 feet, the hole having a diameter of 6 inches. The well is pumped every day at the rate of 50 gallons per minute without exhausting the supply of water. The solid rock was reached at a depth of 50 feet from the surface. An examination of the water has been made by Mr. Milton L. Hersey with the following results:—

"Total solids—600 parts per million (42 grains to the gallon).

Observations on Ignition—No charring whatever.

Residue—Alkaline, on account of small amount of bicarbonate of soda naturally present in the water.

Chlorine—30·4 parts per million (2·13 grains to the gallon).

Oxygen consumed—·155 parts per million.

The water although hard is entirely satisfactory for drinking purposes."

21.—The Dominion Wadding Company—Corner of Willium & Vinet streets, Ste. Cunégonde.

The Dominion Wadding Company's well.

This well is within 400 feet of the Lachine canal. Water was struck in 'a hard rock crevice' at a depth of 160 feet from the surface and the boring was continued for an additional 15 feet, when the work was stopped as a sufficient supply of water had been obtained. The hole is 6 inches in diameter and the water rose to within eight feet of the surface. The boring first passed through Drift containing "boulders," rock being reached at a depth of 90 feet. An abundant supply of good water is obtained, which is used in bleaching cotton.

22-25.—Messrs. William Dow and Co.—186-188 Colborne street.

William Dow & Co's well.

Four wells were sunk on this property with very different results. They were all $4\frac{3}{4}$ inches in diameter.

The first was sunk to a depth of 360 feet and yielded 24,000 gallons a day of water which is stated to be pure and it rises to within 50 feet of the surface.

The second was bored to a depth of 420 feet, but the amount of water obtained was too small to make the well of any value. It, however, rose to within 40 feet of the surface.

The third well was bored to a depth of 430 feet, that is, to practically, the same depth as the last, but yields 60,000 gallons per diem, the water being slightly sulphurous and rising to within 30 feet of the surface.

The fourth well which was put down on this property lies toward the corner of Inspector street and is 830 feet deep. It is practically dry. The firm however find that it can more economically employ water obtained from the City Service and they have consequently abandoned these borings. (*See figure 7.*)

26.—Alexander Drummond, Esq.—Petite Côte.

This well is 500 feet deep and yields 350 gallons an hour, the water rising to within 50 feet of the surface. The rock lies five feet below the surface.

27.—Sir George A. Drummond—Beaconsfield.

Sir George A. Drummond's well.

In boring this well, the drill first passed through 10 feet of drift, followed by 415 feet of limestone. At 425, water was obtained which rose to within 10 feet of the surface. It is abundant but hard. A partial log of the borings, from 215 to 360 feet was preserved, and these have been examined with the following results :

From 215 to 320 feet the rock is a dark gray semi-crystalline limestone, somewhat impure and bituminous.

At 325 feet the rock is a light-gray dolomitic limestone which is followed at 340 feet by a light gray highly siliceous bed with practically no carbonates.

The rock at 350 feet is a light-gray dolomitic limestone which is succeeded at 360 feet by a dark gray bituminous limestone.

From this examination it is evident that this well at the 360-foot level has not passed out of the Chazy formation, there being no beds comparable to the Calciferous sand-rock which underlies the Chazy.

The well yields 1,500 gallons per hour. (*See figure 9.*)

28.—J. N. Drummond, Esq.—Lot 199, Petite Côte.

This well was sunk to the depth of 223 feet in the limestone. At the 200 foot level a bed of very hard rock was encountered, beneath which was the water-bearing stratum or band. This had a honeycombed character, representing either a bed of impure limestone rendered porous by the removal of the soluble portion of the rock, or, possibly, a shattered zone filled by a friction breccia. The water rises to within twenty-five or thirty feet of the surface, and continued pumping fails to lower it below that level. The water is clear and soft with a slight sulphurous taste. (*See* No. 84 and *figure 10.*)

29.—H. A. Ekers, Esq.—Lot 208, Petite Côte.

In this well, water was struck at 325 feet, limestone being the only rock encountered. The water is of a medium hardness and maintains a constant level at 33 feet below the surface. The well yields 600 gallons per hour. (*See figure 10.*)

Well at Eker's brewery.

30.—Ekers' Brewery—409 St. Lawrence street.

This well is 600 feet deep, the first 70 feet being in boulder clay or "hardpan". The water rises to within ten feet of the surface, but on pumping the level is lowered to forty feet. Continued pumping fails to lower it furthur. The well has yielded as much as 25,000 gallons in 24 hours, but its maximum capacity is unknown. A partial analysis of the water, by Dr. Ruttan of McGill University, made on a sample collected on May 25, 1892, gave the following results :—

Total solids	392 parts per million. (=27·44 grs. per Imp. gall.)
Ash, after ignition	234 parts per million.
Organic and volatile	158 " "
Chlorine	40 " "
Nitrogen, as free and saline ammonia	0·057 parts per million.
Albuminoid ammonia	0·066 "
Nitrates	0·799 "

(*See figure 7.*)

31 and 32.—Excelsior Woollen Mills—967 Ontario street.

Wells at Excelsior Woollen Mills.

Three wells were sunk on this property within a distance of about 200 feet from one another. The results obtained, however, in the three cases, were very different.

The first well was sunk to a depth of 300 feet and yielded practically no water. The second well was sunk to a depth of 812 feet, 60 feet of "hard pan" being penetrated before the limestone was reached. Water was first obtained at about 600 feet, but the boring was continued to a further depth of 212 feet in the hope of obtaining a larger quantity. The water is pure and free from sulphur and is pumped from an 80-foot level. The maximum quantity which the well yields, however, is only about 5,000 gallons a day. In the morning, when the pump is started, the water level is 100 feet below the surface, but during the pumping it is gradually lowered to 180 feet, at which it remains constant. The diameter of this hole is 6 inches in the drift, after which it is reduced to 4 inches in diameter, the hole being lined to a depth of 400 feet. Samples of the borings from this well were obtained down to the 340-foot level, the rock on examination proving to belong to the Trenton limestone. Before the heavy earthquake which was experienced in the year 1897, the flow of this well was about double that which it has at present.

The third well was sunk at a depth of 754 feet. Some water was struck at 500 feet and a further supply was obtained at 740 feet. The well now yields 3,600 gallons an hour, or about 86,000 gallons a day. In this well the water rises to within 20 feet of the surface. The hole has a diameter of 10 inches at the surface, after which it decreases to 6 inches. The rock is 35 feet from the surface.

These wells are interesting as showing the great variations encountered within a very limited area, not only in yield of water but also in the height to which the water rises, as well as in the thickness of the drift covering. Mr. William Bell, who drilled the holes, states that there was distinct evidence of the existence of fissures and crevices in the limestone through which these borings passed. (*See figure 7.*)

The Fenlin Leather Company's well.

34.—The Fenlin Leather Company—141 Frontenac street.

This well is 1025 feet deep and might be classed as a dry well, the amount of water obtained (4,800 gallons in 24 hours) being too small to warrant the well being pumped. The rock lies 60 feet from the surface.

35.—M. Gallbert, Esq., 929 St. Catherine street.

This well is 454 feet deep, of which the upper 56 feet is in Drift. The water rises to within five or six feet from the surface, and the amount obtained daily (not the maximum capacity) is 25,000 gallons. The diameter of the bore is 4 inches.

A partial analysis of the water was made by Mr. Milton Hersey, M.A.Sc., and gave the following results, stated in grains per Imperial gallon:

Bicarbonates of Sodium, Magnesium and Lime, and Sodium Sulphate	52·20
Chlorides of Sodium and Potassium	6·25
Silica	1·65
Oxides of Iron and Alumina	trace
Total solids per Imperial gallon	60·10

The water has a distinct alkaline reaction, a slight mineral taste and was somewhat turbid from suspended clayey matter. The temperature is constant at 51° F. throughout the year. (*See figure 7*)

36.—H. Gatehouse, Esq.—808-810, Dorchester street, Montreal.

The well is 750 feet deep and has a capacity of 20,000 gallons of water per diem (24 hours). The water is of good quality and rises to within thirty feet of the surface. The solid rock was reached at a depth of 46 feet from the surface.

37.—The Globe Woollen Mills Company—219, DeLorimier avenue, (Cadastral No. 1,492) St. Mary's Ward.

The well is 410 feet deep, 35 feet in the boulder clay and the remainder in a limestone of uniform hardness. The water rises to within ten feet of the surface and 2,800 gallons are pumped per hour. A chemical examination made by Prof. J. T. Donald, on Nov. 13, 1890, gave the following results, the figures being grains per Imperial gallon :—

'Mineral matter, consisting principally of Calcium Sulphate, with a small amount of Magnesium Sulphate, 49·63. The sulphates render the water hard, but, apart from these, it contains nothing to render it unsuited for use in dyeing.' (*See figure 7.*)

Gould Cold Storage Company's wells.

38 and 39.—The Gould Cold Storage Company—corner Grey Nun and William streets. Two wells have been put down on this property. The first of these was sunk to a depth of 500 feet, at which level the drill was lost, having become jammed in a crevice in the rock. It was found impossible to recover it and operations were not resumed. The well, therefore, was abandoned, no water having being obtained.

In the second well, water was struck at 360 feet, a yield of 10,000 gallons per diem being obtained. The boring was then continued to a depth of 1,301 feet in the hope of securing an additional supply, but without success. The water is said to be pure and it rises to within 40 feet of the surface, The drift covering here is heavy, being 73 feet thick.

40. A. Goyer, Esq.—Frontenac Cadastral No. 1,697, Hochelaga ward.

In boring this well, water was obtained at a depth of 375 feet, the upper 30 feet being through drift. The water is soft. It rises to within 10 feet of the surface. The maximum capacity of the well is about 9,000 gallons per day. (*See figure 8.*)

41. F. Goyer, Esq.—Côte de Neige village.

This well is 250 feet deep, limestone being struck about 25 feet below the surface. The water which is very hard, rises to within 10 feet of the surface. The maximum capacity of the well is not known, but at present from 8,000 to 9,000 gallons are pumped daily.

42. M. Grosboyau, Esq.—1,675 Papineau avenue.

Cadastral No. 161 DeLorimier municipality. This well is 350 feet deep and is wholly in limestone. The water which is soft rises to within 12 feet of the surface. (*See figure 8.*)

45. A. Hobbs, Esq.—Outremont.—Near Canadian Pacific Railway Company's Round House.

This well is 240 feet deep and has a capacity of 48,000 gallons in 24 hours. The water is of good quality and rises to the surface. The hole is six inches in diameter and the rock was met with five feet below the surface.

46. Edward Hughes, Esq.—Lot 487 Cote St. Michel.

The well is 75 feet deep, wholly in limestone. The water-level is 20 feet below the surface. The water is soft and can be obtained in considerable quantity.

Messrs. Laing & Sons' well.

47. Messrs Laing & Sons—Corner of St. Catherine and Parthenais streets.

The well has a depth of 325 feet, of which the upper 56 feet is in the boulder clay, and the lower 269 feet in limestone.

The water rises to within 30 feet of the surface, and the well is fitted with a pump having a 36 inch stroke which delivers a regular supply at the rate of 36,000 gallons per day.

In 1891, a few weeks after the well had been completed, the water was examined by Prof. J. T. Donald, and the following is the result of a partial analysis, stated in grains per Imperial gallon :—

*Calcium Carbonate	14.32
Alkaline Carbonates with a little Silica	5.31
Sodium Chloride	9.38
Calcium Sulphate	12.65
Suspended matter	2.04
Total	43.70

The suspended matter shown in the analysis caused a turbidity which continued even after the well had been pumped for several weeks. Later on, however, this disappeared and a perfectly clear water was obtained. For comparison of this water with that of the Laurentian baths, see page 47.

Well at the Laurentian Baths.

48. The Laurentian Baths, Messrs. Robert White and Company—208 Craig street.

The well is 285 feet deep, of which the upper 60 feet is in drift—clays and gravels—and the lower 225 feet in limestone. Water was struck at 270 feet. The water rose in a pipe to a height of 20 feet above the surface of the ground, and flowed at the rate of 10,000 gallons in 24 hours. At times, however, the pressure has been found to vary somewhat. On one occasion shortly after the boring was completed the water level at 6 p. m. barely reached the surface, but during the night the water overflowed the 20-foot pipe and flooded the building. The well is now pumped and yields 40,000 gallons per day.

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*With a little magnesium carbonate.

Four analyses, showing the composition of the water at intervals during a period of twelve years, have been made by Prof. J. T. Donald, and are given below, in grains per Imperial gallon.

Constituents.	October 28, 1891.	August 26, 1892.	March 31, 1896.	January 1903.
Calcium Bicarbonate	Heavy trace.		1·98	1·78
Magnesium Bicarbonate			1 72	1·13
Sodium Bicarbonate	27·25*	26·74*	32·37	22·37
Sodium Sulphate	6·85	·23	9·30	9·44
Calcium Sulphate		3·47		
Magnesium Sulphate		1·69		
Sodium Chloride	2·32	9·59	5·40	5·38
Potassium Chloride			·77	·43
Silica			·43	·49
Total	36·42	41·72	51·97	41 02

An interesting point in connection with this water is the very small amount of the carbonates of lime and magnesia, and the large proportion of the alkaline carbonates present. This is of especial interest in view of the fact that in the water from the well of Messrs. Laing & Co., a short distance away, the relative proportion of these constituents is reversed.† (See analysis, p. 46). No samples of the borings were preserved with the exception of a small fragment brought up from the level at which the water was struck. This on examination proved not to be limestone but a soft black shaly rock traversed by a few veinlets of a light coloured impure dolomite. Before the blowpipe both the rock and veins fuse on the edges to a blebby glass. This shale is evidently part of one of the beds which occur interstratified with the Trenton limestone. To the passage of the water through this shale instead of through the limestone may be due the presence of lime in so small an amount.

Another analysis, by Mr. Milton Hersey, M. A. Sc., gave the following results in grains per Imperial gallon:—

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* Alkaline Carbonates with a little Silica.

† The Waters of Two Artesian Wells in the Eastern Part of the City of Montreal. By J. T. Donald. Can. Rec. of Science, Vol. V, No. 2, April, 1892.

Chlorides of Sodium and Potassium	6·17
Sulphates of Magnesium, Calcium and Sodium	45·37
Silica	1·65
Total	53·19

It is probable that in this analysis the large proportion of sulphates shown is due to the calcium, magnesium and sodium having been calculated as sulphates, although they really exist in part at least in other forms.

The earthquake which occurred in the autumn of 1893 produced a very perceptible turbidity in the water, which lasted for about a day and a half.

Part of the water pumped is drawn off immediately and used in the manufacture of soda water and ginger ale, or used for drinking purposes, but the greater part is used to supply the large and well equipped swimming bath, Turkish baths, etc., on the premises. This well, considering the short distance which it was necessary to bore, and the character and the volume of the water obtained, must be regarded as one of the most successful borings which has yet been made on the Island of Montreal. (*See figure 7*).

The Laurie Engine Company's well.

49.—The Laurie Engine Company—1020, St. Catherine street.

Water was first struck after boring through 65 feet of drift and 85 feet of limestone, but boring was continued to a depth of 300 feet. The water is clear and sparkling with a faint chalybeate taste, and rises to within fifteen feet of the surface. It is too hard to be used in boilers. 27,000 gallons are pumped daily. (*See figure 7 and page 63*).

51.—The Longue Pointe Asylum—Longue Pointe.

Water was obtained at a depth of 300 feet from the surface, the well yielding nearly 9,600 gallons per diem. The boring was then continued to a depth of 2,000 feet, but no further supplies of water were secured. The rock here is about 4 feet from the surface.

An interesting fact in connection with this well is that about half a mile to the north of the spot where the boring was located, a spring issues from the country rock with a flow of 2,500 gallons an hour, or 60,000 gallons per diem, the water rising through a rather large fissure which here reaches the surface; while along the line of the boring, although 2,000 feet of strata are traversed, only a single small water-bearing crevice was encountered.

53.—A. Martin, Esq.—Lot 1010, Parish of Lachine.

In sinking this well, gas and water were struck at 460 feet below the surface. The gas burned for 12 hours, when the supply became exhausted. Boring was then continued to 740 feet without obtaining any greater volume of water. The drift consists mainly of "hardpan" and is 65 feet thick. Between the hardpan and the limestone a thin layer of quicksand was encountered. The water rises to within eleven feet of the surface. It is of a good quality but very hard. If it is covered for some time, a faint sulphurous odour is detected. The supply is limited, the well yielding only about 100 gallons per hour. The diameter of the hole is 6 inches.

55.—Mrs. J. McIntosh—Lot 429, Côte St. Michel.

The well is 120 feet deep and the water rises to within four or five feet of the surface. It is soft with slight chalybeate and sulphurous taste. The latter, however, disappears on allowing the water to stand for some time. A steam pump is used to raise the water, the pipe being an inch in diameter.

57.—Montreal Brewing Company—1334 Notre Dame street (Lot 19 St. James Ward.)

The Montreal Brewing Company's well.

This well is 502 feet deep, the first 80 feet being in "hardpan." Water was first struck at 497 feet, and from the working of the drill it would seem that the water rose from a fissure about eight inches wide. The water level is 36 feet below the surface. The maximum capacity of the well is not known, but it has yielded 126,000 gallons in 24 hours. The bore is $4\frac{5}{8}$ inches in diameter.

An analysis of the water taken from the well on April 9, 1895, was made by Prof. J. T. Donald. The results are as follows, expressed in grains per Imperial gallon :—

Calcium Carbonate	15·03
Magnesium Carbonate	8·19
Ferrous Carbonate	1·43
Sodium Carbonate	3·75
Sodium Chloride	11·51
Calcium Sulphate	25·80
Silica	1·31
Total	67·02

Free and loosely combined Carbon Dioxide..........	17·35
Hardness..	21·50

(*See figure 7.*)

58.—Mount Royal Cemetery, near the Crema'ory.

This well is 354 feet deep and has a capacity of 36,000 gallons in 24 hours. The hole is 4¾ inches in diameter and the water, which is of good quality, rises to within twenty-five feet of the surface. The boring starts in solid rock.

The Montreal Cold Storage Company's well.

59.—The Montreal Cold Storage Company—604-610 St.Paul street.

This well is 1020 feet deep, the first 60 feet being in drift. Water was obtained which rose to the surface, but the flow was irregular owing to the escape of gas. A pump arranged to take water from the 400 foot level was then fitted in the well. The first water obtained was dark in colour, owing to the distribution through it of minute flecks of sulphide of iron. At the time the well was visited the water was running alternately darker and clearer at intervals of a few minutes, giving off gas which when ignited burned with a bright flame. After pumping for a time the pressure of the gas became so great that the pump rod could not be forced down, and operations had to be discontinued until the gas escaped. If the well were fitted with a pump properly constructed for the purpose, this difficulty arising from the presence of the gas would disappear. It is quite probable that the sulphide of iron is produced by the action of the sulphuretted water upon the pump rods and iron casing, and that by continuous pumping its amount would greatly decrease. (*See figure 7.*)

63.—The Montreal Hunt Club—Outremont.

This well was started on rock at surface and was drilled to a depth of 226 feet. The boring is six inches in diameter and yields 36,000 gallons of good water in 24 hours; the water rises, within ten feet of its surface.

65.—Montreal Milling Company—Park Avenue, Outremont.

This well is 345 feet deep, and is wholly in limestone. Water was struck at 337 feet. but boring was continued 8 feet farther, the last foot being in a rock with a honeycombed or porous structure.

The water level is 25 feet below the surface, and this was not lowered after pumping 1,700 gallons per hour for 144 hours. The water is saline and is unfit for use.

The diameter of the well is 5 inches. In boring it was found that the rock varied somewhat in hardness, the progress of the drill varying from 5 feet to 20 feet in 12 hours (*See figure 8.*)

66.—Mount Royal Park.

This well was sunk on the Mountain opposite the water tank. It is 66 feet deep, 4 feet being in drift and 62 feet in the Essexite rock which composes the greater part of the Mountain. The diameter of the hole is 4 inches. The water is pure and abundant; in the spring time it rises to the surface but does not overflow.

67.—Montreal Weaving Company—595 Clarke street, Ville St. Louis.

The Montreal Weaving Company's well.

This well is 420 feet deep and with the exception of 5 feet of drift it is wholly in the limestone. At the 200 feet level a bed of very hard rock was struck through which the drill went very slowly. This bed was probably, an intercalated still of igneous rock. The water rises to within 125 feet of the surface It is pure and soft. 800 gallons a day are now pumped, but the well has a capacity of 12,000 in 24 hours (*See figure 8.*)

68.—G. Nantel, Esq.—Terra Nova, Côte des Neiges.

This well was bored to the depth of 600 feet, of which the first five feet were in drift and the rest in limestone. The water is very pure and abundant. It does not rise to the surface. (*See figure 9.*)

69.—Outremont Milling Company—Outremont.

The well has a capacity of 43,000 gallons in 24 hours. This boring is 4 inches in diameter and has been carried to a depth of 335 feet. The water is very hard and rises to within 25 feet of the surface. (*See figure 8.*)

70.—Judge Pagnuelo—Pagnuelo avenue, Outremont.

This well has been sunk in limestone to a depth of 700 feet. Only a comparatively small amount of water being obtained work was discontinued at that level. The well is stated to have a capacity of about 7,000 gallons in 24 hours.

71.—Mrs. Quiggley—South end of Lot 9, Longue Pointe.

The well is 100 feet deep, 90 feet being in drift and 10 feet in limestone. It yields 200 gallons per hour. The water is of medium hardness, and rises to within nine feet of the surface. (*See figure 8.*)

72.—A. Ramsay, Esq.—Inspector street, (Cadastral No. 1758 St. Antoine ward).

Water was struck at 800 feet and rose to within fourteen feet of the surface. The Troy Steam Laundry attempted to use it for washing but it was found to be too hard. The well has a capacity of about 2,000 gallons per hour.

73.—A. Ramsay, Esq.—Codastral No. 282, Lot 4, Westmount.

This well was sunk through solid rock to a depth of 880 feet, water being first struck at 700 feet. The water rises to within eighteen feet of the surface; it is of good quality although somewhat harder than that of the St. Lawrence river, but it is quite suitable for all domestic purposes. The capacity of the well is about 15,000 gallons per diem.

74.—M. Rhéaume, Esq.—Foundry, Intersection of Canadian Pacific Railway track and Carrière street, Ville St. Louis.

In boring this well, 10 feet of sandy drift and 290 feet of limestone were passed through before water was obtained. The water is rather hard; it rises to the surface but does not overflow. At the time of inquiry only 100 gallons were being used daily, but the capacity of the well is about 24,000 gallons in 24 hours. (*See figure 8.*)

Messrs. Rowan Brothers' well.

75.—Messrs. Rowan Brothers, Ginger Ale Manufacturers—618, Beaudry street.

This boring has a depth of 600 feet, of which the first 70 feet was through boulder clay and gravels. The water rises to within sixty feet of the surface and the well has a tested capacity of 5,000 gallons per hour. The water is pure and the amount used daily in the manufacture of ginger ale, soda water, etc., varies from 1,500 to 2,000 gallons. This is sometimes referred to as the Mooney well. (*See figure 7*).

76.—The Royal Golf Club—Dixie.

This well is 450 feet deep and yields 28,800 gallons per day, the water rising to within fifteen feet of the surface. The water is stated to be of good quality. The drift covering here is 37 feet thick.

77.—The Salvador Brewing Company, (Reinhardt's brewery)—617 St. Paul street.

This hole is 550 feet deep and has a diameter of 4½ inches. The rock was met with 62 feet from the surface. The well gives too little water to be of much value, and like other wells of this yield might be classed as a dry well. The actual yield is from 300 to 400 gallons an hour, or about 8,000 gallons per diem.

78.—The Sault au Recollet College—Black river.

Well at Sault au Recollet College.

In boring this well 35 feet of drift was first traversed when the solid rock was reached. The boring was continued in this, the hole being 6 inches in diameter, and at a depth of 100 feet from the surface water was struck which could be pumped at the rate of 2,000 gallons per hour. This water, however was hard, and it was therefore decided to continue boring in the hope of obtaining a supply of better water. At a depth of 490 feet from the surface, a second water-bearing crevice or band was struck, and in this the water was soft. The upper hard water was accordingly cut off from the hole, and the soft water derived from the lower source alone was used. This rises to within thirty feet of the surface and when pumped yields 500 gallons per hour.

79.—The Shawinigan Water and Power Company—Maisonneuve.

This hole is 1,017 feet deep, but yields only 4,800 gallons a day, the quantity being too small to be of value. Rock lies 60 feet from the surface.

80.—Convent of the Sisters of Providence—Notre Dame de Grâce.

The drilling was carried to a depth of 320 feet. The hole is 4½ inches in diameter. The rock was encountered 22 feet from the surface. The well yields 48,000 gallons per diem and the water is said to be pure.

81.—The Stanley Dry Plate Company—613 Lagauchetière street.

The well is 1,300 feet deep and yields about 8,400 gallons of good water in 24 hours. This hole is 4¾ inches in diameter, and the water rises to within 30 feet of the surface. The drift is here 40 feet thick. (*See figure 7.*)

82.—St. Laurent Convent—St. Laurent.

In this well water was obtained at 250 feet. The water rose to the surface. It is hard, with a slight sulphurous taste and the supply is abundant. (*See figure 9.*)

83.—St. Laurent College,—St. Laurent.

Wells at St. Laurent College and convent.

The well is 487 feet deep. In boring, the drill first passed through 31 feet of "hardpan" and then through 456 feet of limestone. The normal water level is 13 feet below the surface. On pumping, this is lowered to 27 feet, at which it remains until pumping is suspended.

The water is pure and soft. A rough analysis at the college gave small amounts of lime and magnesia. The capacity of the well is not known, but it easily yields 10,000 gallons a day. (*See figure 9.*)

84.—Mr. Stewart, Lot 195, Petite Côte.

This well is similar to No. 28 in every particular and doubtless has its source in the same water-bearing zone or bed. (*See page 42 and figure 10.*)

85.—T. A. Trenholme, Esq.—Cadastral No. 141, Côte St. Pierre.

In this well water was obtained at the depth of 185 feet, the drill passing through 100 feet of drift and 85 feet of limestone. The water rises to within twenty-five feet of the surface; it is very pure and 6,000 gallons are pumped daily. (*See figure 9.*)

86.—T. A. Trenholme, Esq., Thorne Hill, Côte St. Pierre.

This well is 175 feet deep, 75 feet of drift and 100 feet of limestone being penetrated. The water is pure and abundant.

Turkish bath well.

87.—Turkish Bath Hotel, 140 St. Monique street.

This well is 1550 feet deep, of which the first 50 feet is in "hardpan." Water was struck which rose 6 feet above the surface. Although a flowing well, it is necessary to pump it in order to obtain the amount of water required. The capacity, without lowering the water level much below the surface, is between 4,000 and 5,000 gallons per day. The water is soft and slightly sulphurous.

Specimens of the drillings from different levels were obtained and these have been examined with the view of ascertaining the character and thickness of the formations penetrated by the boring. The results show that the well is wholly in the limestone series. Here and there, however, igneous rocks have been encountered, which are of the nature of dykes or intercalated sills.

At a depth of 50 feet from the surface Trenton limestone was struck, which formation continued down to about the 525 foot level, when fossils determined by Dr. Ami as referable to the Birdseye formation were found. At 640 feet, fossils of the Chazy were detected. Judging from the scanty evidence obtained from fossil remains, combined with the results of a chemical examination of the rock, it seems that this formation extends downwards to about the 1425th foot level. At this depth magnesian limestones, more or less impure and siliceous, were met with, and these continue down to the 1540th foot level. The last 10 feet consisted of sandstones which represent the more siliceous beds of the Calciferous, to which formation the magnesian limestones presumably belong.

The formations traversed and their thicknesses may be represented in tabular form as follows:

Pleistocene (drift)	50 feet
Trenton and Birdseye Limestone	590 "
Chazy Limestone	785 "
Calciferous Limestone	125 "
Total	1550 feet

The Potsdam sandstone was not reached in this boring and it is probable from the thickness of the Calciferous traversed that the sandstone is considerably below the 1550th foot level. (*See figure 7.*)

88.—The Wire and Cable Compang—Corner Guy and St. James streets.

Wire and Cable Company's well.

Water was struck 960 feet from the surface, and sinking was then continued to a depth of 1055 feet in hope of obtaining a larger supply of water, but without success. The water just rises to the surface. The yield of the well was tested by pumping for 14 consecutive hours, at the rate of 3,000 gallons an hour. This resulted in the lowering of the level of the water by 16 feet, which lowering took place when the pumping began, after which time the water level sunk no further. The hole is 6 inches in diameter down to a depth of 40 feet from the surface, below which the diameter is 4¾ inches. The solid rock was met with 57 feet from the surface.

An analysis of the water by Dr. J. T. Donald gave the following results in grains per Imperial gallon:—

Carbonate of Lime	22·09
Carbonate of Magnesia	2·79
Carbonate of Iron	·53
Carbonate of Soda	12·20
Sulphate of Lime	1·24
Chloride of Sodium	1·55
Total solids	40·40

Wells affording Saline Waters or Waters containing Sulphuretted Hydrogen.

Canadian Pacific Railway Company's well at Outremont.

13. Canadian Pacific Railway—Outremont, North End of Cadastral Lot No. 35, Parish of Montreal.

After traversing 25 feet of clay, the drill struck rock and the boring was continued to the depth of 410 feet. The water level is 8 feet below the surface, but on pumping at the rate of 8,000 gallons per hour the level is lowered to 22 feet, 6 inches. The diameter of the hole for the first 300 feet is 5½ inches, and is then reduced to 4 inches.

The water is not pure, being "charged with sulphur and salts" and is unsuitable for use in locomotives. An analysis supplied by the company shows it to have the following composition, in grains per Imperial gallon :

Calcium Carbonate	15·133
Magnesium Carbonate	4.347
Potassium Chloride	1·34
Sodium Silicate ($Na_2 Si O_3$)	2·56
Sodium Sulphate	3·21
Calcium Sulphate	9·09
Oxides of Iron and Alumina	0·42
Total	36·090

(*See figure 8.*)

Messrs. Dawes & Co's well.

19. Messrs. Dawes & Co.—Lot 202D Lachine.

At a depth of 1,003 feet, water was obtained which rose to within 10 feet of the surface. At first, pumping was carried on daily for 3 or 4 hours at 60 lbs. pressure, through a 2 inch pipe, without lowering the level. The temperature of the water was constant at 48° F. throughout the year. An examination of the water was made by E. B. Kenrick Esq. of Winnipeg with the following results :—

The water was somewhat turbid.

Solids dried at 100° C, 4670 parts per million=326·9 grains per Imperial gallon.

Loss on ignition 1050 parts per million.

Nitrogen as Albuminoid Ammonia	0·06
" as Free and Saline	0·31
" as Nitrates and Nitrites	0·21

Chlorine as Chlorides	640·00
Phosphates	trace.
Oxygen absorbed at 80° F. in 15 minutes	0·336
" " 4 hours	0·744

On ignition, there was no blackening of the total solids 'I am of the opinion that the sample is fairly free from organic impurities, but contains too much saline matter to be a first class water.'

An analysis made by Frank Faulkner, Esq. is as follows :—

Free Ammonia	0.720 parts per million.
Albuminoid Ammonia	0.170 " "

The following results are given in grains per Imperial gallon :

Chlorine	44.80
Nitric Acid	None.
Sulphuric Acid	119.28
Calcium Carbonate	20.58
Lime otherwise combined	51.83
Magnesia	22.36
Soda	Undet.
Saline residue	271.60
Organic and Volatile matter	54.46
Total solid residue	326.06

The following represents according to Mr. Faulkner the most probable composition of the saline residue.

Calcium Carbonate	20.58
Calcium Sulphate	125.84
Magnesium Sulphate	67.86
Sodium Chloride	73.92
Total	288.23

(*See figure 9.*)

20. W. B. Dickson, Esq.—Lot 21 Longue Pointe.

This well is 170 feet deep, 100 feet being in drift and 70 in limestone. The water rises to within 13 feet of the surface. It is impure, saline, and strongly impregnated with sulphuretted hydrogen. The water pumped the first two days was perfectly black, but it gradually became clearer. (*See figure 8.*)

43. Chas. Gurd, Esq.—39-42 Jurors street. Lot 696.

In sinking this well, limestone was struck 18 feet from the surface, and water was first obtained at 440 feet but the supply was very limited, becoming exhausted in 8 hours when pumped through a 2 inch pipe. Boring was then continued to 512 feet and water was struck which rose to the surface and flowed at the rate of 800 gallons in 24 hours. On pumping, however, it will yield 4,000 gallons in the same time, but if forced above that the well is drained below the 360 foot level where the pipe ends, and some hours elapse before it refills. The water is strongly impregnated with sulphuretted hydrogen gas, resembling in this respect the water obtained at Viau's well, Maisonneuve. (*See figure 7.*)

44. Mr. Hampson—Lot 40 Longue Pointe.

This well was sunk in limestone to the depth of 502 feet, when an impure saline water strongly impregnated with sulphuretted hydrogen, was struck. The water is unfit for use.

Well of Messrs. Lowell and Christmas.

52. Messrs Lovell and Christmas—63 William street.

This hole is 612 feet deep and has a diameter of 6 inches. The water is slightly sulphurous and rises to within 30 feet of the surface. The well has a capacity of 60,000 gallons a day, and the firm in 1903 were regularly pumping 43,200 gallons per diem. When pumping, the water level is lowered to 168 feet, below the surface. The rock is met with at a depth of 62 feet. This water was examined by Milton L. Hersey, M. App. Sc. who reports upon it as follows :

'Odor of water	Sulphuretted hydrogen.
Appearance of water	Turbid, when pumping is stopped.
Temperature of water	50° F.
Total solid matter on evaporation	600 parts per million.
Solids volatile on ignition	130 parts per million.
Odor of solids on ignition	none.
Charring of solids on ignition	none.
Organic matter (oxygen consumed)	1.35 parts per million.

(This is really not due to organic matter but to the presence of sulphuretted hydrogen and other sulphur compounds).

Chlorine as chlorides	127.71 parts per million.
Free ammonia	0,784 parts per million.

(This quantity of free ammonia is more apparent than real on account of the presence of sulphuretted hydrogen).

Albuminoid Ammonia	0.051 parts per million.
Total Ammonia	0.835 parts per million.
Nitrogen as Nitrites	very faint traces.
Nitrogen as Nitrates	none.
Gas producing bacteria in phenol-dextrose broth	none whatever.

I consider this water free from objectionable contamination so far as its sanitary properties are concerned.'

54. Messrs. A. S. and W. H. Masterman—2082½ Notre Dame street, Cadastral No. 1303 St. Anne's ward.

Well of Messrs. A. S. and W. H. Masterman.

In the case of this well rock was struck 68 feet from the surface, and water was obtained at 750 feet. Boring was continued to 800 feet, the last 50 feet being to provide a sink-hole for the sediment. The water level is 10 feet, 10 inches, below the surface, and the supply is stated to be undiminished when pumped at the rate of 3,000 gallons per hour.

An analysis by Dr. G. P. Girdwood is given below, the results being stated in grains per Imperial gallon :

Calcium Carbonate	23.35
Ferrous Carbonate	0.44
Sodium Chloride	15.36
Magnesium Chloride	13.11
Calcium Chloride	26.80
Calcium Sulphate	1.28
Silica	3.08
Total	83.42

Free ammonia	.20 parts per million.
Albuminoid ammonia	.11 parts per million.

Some Sulphuretted Hydrogen is also present.

The earthquake of 1897 did not affect this well, but that of 1895 broke the iron casing 40 feet below the surface and necessitated its removal. (*See figure 7.*)

56. Messrs J. H. R. Molson and Brothers—1,006, Notre Dame street.

Well of Messrs. J. H. R. Molson and Brothers.

The well is situated on Cadastral No. 28 of St. Mary's ward, being the south corner of Notre Dame and Monarque streets, at what is known as Molson's Brewery. Water was obtained at adepth of 420 feet. The boring was then continued to a depth of 672 feet without obtaining any increased supply. The water rises to within twenty-four feet of the surface, but is lowered by pumping to eighty-three feet, the well yielding 4,700 gallons per hour. The hole is 8½ inches in diameter down to the solid rock, then 6 inches for the next forty-two feet, when it is reduced to a diameter of 4¾ inches. As usual in the wells in this lower part of the city, the drift covering is very thick, here amounting to 83 feet. The temperature of the water is 52° Fah.

The results of an analysis of the water, made for Messrs. J. H. R. Molson & Brothers, are as follows, stated in parts per 100,000 and also in grains per Imperial gallon :—

	Parts per 100,000.	Grains to the gallon.
Calcium Carbonate	11.35	7.95
Magnesium Carbonate	8.83	6.18
Sodium Sulphate	40.77	28.54
Sodium Chloride	22.23	15.56
Sodium Carbonate	16.44	11.51
Potassium Sulphate	3.01	2.11
Silicates of Iron and Alumina	2.13	1.49
Fixed Mineral Salts	104.76	73.34
Total Solid Residue at 127° C.	107.64	75.35
Loss on gentle ignition of residue	2.88	2.02
Free Ammonia	.018	
Albuminoid Ammonia	.005	
Nitrates	Nil.	
Nitrites	Nil.	
Chlorine	13.49	9.44
Phosphates	Trace.	
Iron in Solution	Nil.	
Total Hardness (soap test)		24.40
Temporary Hardness (soap test)		11.60
Permanent do do		12.80

The water has a saline taste, a marshy odour and an opalescent colour. It gives an alkaline reaction with litmus paper. The "biological condition" of the water is stated by the analyst to be "unsatisfactory ", but this fact as well as the saline character of the water is of little consequence, since the firm requires the water merely for cooling purposes. (*See figure 7.*)

64. The Montreal Locomotive and Machine Company—Longue Pointe.

Well of Montreal Locomotive and machine Company.

This well is 514 feet deep and yields 1,200 gallons an hour, the water rising to within 25 feet of the surface and having a strong odour of sulphuretted hydrogen. The solid rock was encountered 27 feet from the surface.

Two analyses of this water were made by Milton L. Hersey, M. App. Sc., the first being of a sample collected on July 23, 1903, being pumped from a depth of 25 feet below the surface, and the second collected on September 14, 1903, being pumped from a depth of 125 feet.

The results of these analyses are as follows in grains per Imperial gallon :—

	July 23, 1903.	Sept. 14, 1903.
Calcium Carbonate	1.39	none.
Magnesium Carbonate	1.57	trace.
Sodium Sulphate	2.52	4.72
" Chloride	1.51	10.39
" Carbonate	29.00	41.86
Silica	.21	.66
Ferric Oxide Alumina	.50	trace.
Total Solid Matter	36.70	57.63

88. Messrs Viau & Frère—Maisonneuve, Subsection of Lot 5, Longue Pointe.

Well of Messrs. Viau & Frère.

This boring was made in the hope of striking natural gas. Bed rock was encountered after the drill had passed through 90 feet of drift. At 450 feet good water was met with which rose to within 10 or 12 feet of the surface. The boring was continued to a depth of 1,190 feet, when water strongly impregnated with sulphuretted hydrogen was struck, which rose to the surface and flowed at the rate of 5,000 gallons in 24 hours.

The final depth reached was 1,500 feet and it is stated that the only rock encountered was limestone.

On the completion of the well a sample of the water was collected. This was analysed in 1890, by Dr. Frank D. Adams. The water when received for analysis had a faint, yet decided odour of sulphuretted hydrogen, and contained a trifling amount of sediment. The colour of the clear water in a column 2 feet in height was light yellow ; the taste mildly saline ; the reaction faintly alkaline. The specific gravity at 15.5° C. was 1.00631. The total dissolved matter by direct experiment, dried at 180° C. in 1,000 parts by weight of water was 7.4129.

Analysis of water.

The water contained for 1,000 parts by weight :—

Potassa	0.190
Soda	3.3899
Lithia	undetermined.
Lime	0.836
Strontia	undetermined.
Magnesia	0.1165
Ferrous Oxide	undetermined.
Alumina	trace.
Sulphuric Acid	1.6636
Boracic Acid	undetermined.
Carbonic Acid	0.3819
Phosphoric Acid	undetermined.
Chlorine	2.4623
Iodine	0.000027
Bromine	undetermined.
Silica	0.0135
Organic Matter	undetermined
Total	8.130327
Less Oxygen equivalent to Chlorine	0.5555
	7.574827
Sulphuretted Hydrogen—when received	0.0098

The constituents may be assumed to exist in the water combined as follows ; the carbonates being calculated as mono-carbonates, and all the salts being estimated as anydrous.

Calcium Carbonate	0.0855
Magnesium Carbonate	0.2447
Potassium Chloride	0.0301
Sodium Chloride	4.0358
Sodium Sulphate	2.8624

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[*] Geological Survey of Canada. Report of Progress, Vol. IV, 18 R.

Calcium Sulphate	0.0867
Alumina	trace
Silica	0.0135
	7.3587
Carbonic Acid-half combined	0.1658
Carbonic Acid-free	0.0503
	7.5748

These quantities if calculated, for purposes of comparison with the other waters, as grains per Imperial gallon, would be as follows :

Calcium Bicarbonate	8.617
Magnesium Bicarbonate	26.103
Potassium Chloride	2.107
Sodium Chloride	282.506
Sodium Sulphate	200.368
Calcium Sulphate	6.069
Silica	0.945
Alumina	trace
	526.715
Free Carbonic Acid	3.521
Total	530.236

(*See figure 8.*)

DRY WELLS.

33.—The Excelsior Woollen Mills—967 Ontario street. Dry wells.

This well is 300 feet deep.

39.—The Gould Cold Storage Company—20 William street.

This well was sunk to the depth of 500 feet. At that level the drill was lost in a crevice in the rock and, not being recovered, operations were not resumed.

50.—The Laurie Engine Company—1012 St. Catherine Street.

This hole was bored a short distance from the well previously mentioned. (*See page 48.*) It has a depth of 700 feet.

60 and 61.—The Montreal Gas Company—Hochelaga.

Two borings were made, about 600 feet apart, the respective depths being 1850 and 2550 feet. Of the deeper well a set of 20 specimens was obtained from Mr. W. Bell for examination. They were taken from between the 2200 and 2373 foot levels. Without exception they were found to be fine-grained, impure, siliceous dolomites, associated with thin beds of dolomitic shale. At the 2373rd foot level the limestone was so impure that the chips retained their original forms after boiling in dilute hydrochloric acid.

For purposes of comparison, typical specimens of the rock of the Calciferous from Lachute and Ste. Anne's were examined, as well as some from the Chazy and Trenton formations. It was found that the Calciferous specimens were identical in character with the rock obtained from the boring, and it seems highly probable that the Gas Company's borings terminated in the Calciferous sandrock formation.

At 2,200 feet and 2,325 feet respectively, chips were found which are evidently of igneous origin, one a dark basic mica trap, and the other a much decomposed porphyrite. These two are probably fragments of dykes which are connected with the intrusion of Mount Royal.

62.—Montreal Gas Company—Ottawa street.

After boring through 90 feet of "hardpan" and 960 feet of limestone, operations were discontinued.

There are two other wells which are worthy of mention, although they have not been included in the list given above, because in one case the well is not actually on the Island of Montreal, and in the other case the well was bored at a later date than December 31, 1903, having been completed in the spring of 1904.

The Laprairie Pressed Brick Company—Laprairie.

A boring was made through 1,000 feet of shales, without meeting limestone and without obtaining water. This boring not being actually on the Island of Montreal is not included in the tabulated list.

Côte des Neiges Cemetery—Montreal.

This well is of especial interest on account of the fact that it starts at the surface in the Essexite intrusion of Mount-Royal—which underlies the greater part of this cemetery—and continues down this intrusion to a depth of 486 feet. Whether the Essexite maintains a uniform character throughout this whole distance is not known, but the powdered rock brought up from depths of 482 feet and 485 feet, and a fragment of the rock from a depth of 486 feet have been obtained from Mr. William Bell who drilled the hole and they show that the well ended as it began in Essexite. Thin sections made from the fragment obtained from the bottom of the well, show that the Essexite there is of medium grain and very basic in character being composed essentially of Pyroxene and Hornblende with accessory Magnetite, Biotite, Apatite and Pyrite. It is possible that a little Olivine is also present. This rock therefore represents the Pyroxenite differentiation facies which is often largely developed at the surface. It closely resembles certain black varieties of the rock found in the cemetary near the contact of the Nepheline Syenite intrusion where this is quarried at Outremont. The rock from 485 and 486 feet contains a certain amount of plagioclase.

The precise level of the spot where this boring was commenced has not as yet been determined, but is probably somewhere about 500 feet above sea level, so that the hole penetrates the mountain down to about the level of the St. Lawrence River.

It yields but little water. Mr. Bell states that he pumped 1,500 gallons when testing it.

CHEMICAL COMPOSITION OF THE WATERS.

Chemical composition of the waters.

Most of the waters, as has been shown, are potable, but some of them are hard, owing to a considerable content of lime or magnesia salts and are therefore unsuitable for use in steam boilers. Others, however, are soft and adapted for such use. Some few, on the other hand, are impregnated with sulphurous compounds or are too saline in character to be of use except for cooling purposes. As has been mentioned, a throughly satisfactory comparative study of the composition of the various waters cannot be made, owing to the fact that those of which analyses exist have been analyzed by different chemists who may have, and in all probability have to a certain extent at least, followed different plans in combining the different acids and bases, the amounts of the several acids and bases actually determined not being stated. The analyses, furthermore, have been made merely for technical purposes and are in most cases incomplete. A comparative examination of them, however, brings out some interesting points.

Six classes of Dr. Hunt.

Dr. Sterry Hunt, many years ago, made a somewhat extended study of the waters of the mineral springs which at many points rise through the unaltered palæozoic strata of the Provinces of Quebec and Ontario * and found that these might be divided into six classes as follows :

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*Geology of Canada, p. 531 et seq.

Class I. Saline waters containing sodium chloride with large proportions of calcium and magnesium chlorides, sometimes with sulphates. Calcium and magnesium carbonates are present only in very small quantities or are altogether wanting.

Class II. Saline waters which differ from the first in containing beside sodium, calcium and magnesium chlorides, considerable proportions of calcium and magnesium bicarbonates, the latter carbonate usually preponderating.

Class III. Saline waters which contain beside sodium chloride, a portion of sodium carbonate, with calcium and magnesium bicarbonates.

Class IV. In these waters sodium carbonate preponderates. They contain but a small proportion of sodium chloride, and generally hold a much smaller amount of solid matter than the waters of the previous classes.

Class V. Waters containing a large proportion of free sulphuric acid.

Class VI. Neutral saline waters in which calcium, magnesium and alkaline sulphates predominate, chlorides being present only in small amount.

Classes to which the Montreal waters are referable.

The waters from the deep wells of the Montreal district cannot of course in the majority of cases be classed as mineral waters, being for the most part of potable quality, but those among them which are saline waters can be so classed, and all of them rising from the same great plain as the waters studied by Dr. Hunt might be expected to possess the same general characters in respect of the nature of the dissolved materials, although containing these in lesser amount.

An inspection of the analyses given in this Report will show that there are among them no representatives of Dr. Hunt's classes I and V, while some of the waters do not seem to be referable to any of the classes which he has established but to present intermediate characters.

Class II is represented by Messrs. A. S. & W. S. Masterman's well, although the water is not a very highly saline one.

To Class III is to be referred the water of the well put down by Messrs. Belding, Paul & Co.

Several of the waters are clearly referable to Class IV of Dr. Hunt's series, being characterized by a predominance of sodium carbonate. Of these, the water of the Laurentian Baths, that of the Montreal Locomotive and Machine Company, that of the Canadian Pacific

Railway shops at Hochelaga and of Mr. Galibert's well may be instanced. The water obtained by the Wire and Cable Company belongs to this class, although it contains, in addition to the sodium carbonate, a considerable proportion of calcium carbonate and some magnesium carbonate, thus resembling the water from St. Ours, analyzed by Dr. Hunt.

Class VI is represented by the water obtained by Messrs. Dawes & Co., at Lachine.

The waters from the well owned by Messrs. Viau & Frère and that of Messrs. J. H. R. Molson & Brothers, on the other hand, are not referable to any of Dr. Hunt's classes, containing as they do large proportions of sodium chloride and sodium sulphate, with smaller amounts of calcium or magnesium carbonate; the latter water which is much less saline than the former containing in addition a notable quantity of sodium carbonate. In the case of the Viau well, however, as mentioned below, it is known that water enters the bore hole at two distinct levels, the two waters differing in character.

Source of the chlorides and alkaline carbonates.

Among the waters of the first four classes, Dr. Hunt considers the chlorides of the alkalies and alkaline earths (calcium and magnesium) which they contain, to have their origin in the limestones of the underlying palæozoic strata, from the Potsdam or the Trenton inclusive; while the sodium and potassium carbonates he believes to be derived from the argillaceous sediments which make up the Utica and Hudson river formations, these sediments containing alkaline silicates whose slow decomposition yields to the infiltrating water the alkaline carbonates and silicates which characterize the waters of Class IV.

The waters of the latter class, however, on the Island of Montreal cannot find their origin in strata of these ages for the borings all start in much lower rocks. If they derive their alkaline carbonates from shales, it must therefore be from the shaly beds interstratified with the Trenton or Chazy limestones, of the same age as those which Hunt supposes to be the source of these salts in the waters of the Caledonia and Fitzroy Springs of the Ottawa Valley.* In confirmation of this, it will be noted that the several wells above mentioned as affording the soft alkaline waters of Class IV are all comparatively shallow borings, ranging from 266 feet to 567 feet in depth.

Waters of different classes arising from the same fissure or boring.

As an evidence that the different classes of waters have their origin in different strata, Dr. Hunt further mentions that springs which are unlike in composition are often found in close proximity and apparently rising from a common fissure or dislocation; and he mentions among others a case in the Seigniories of Nicolet and La Baie du Febvre, where six springs rise through the Utica shale along a line in a distance of about eight miles. Of these, two belong to Class II, two to Class III and two to Class IV. These last Dr. Hunt considers to be probably derived from the shales, while the others have their source in the underlying limestones and are more or less modified in their ascent.* A somewhat similar diversity of origin must be ascribed to the waters of the Montreal district, where an equally wide range in composition is presented in an area which is much more limited in extent. As has been mentioned, the highly saline waters here usually come from the deeper wells, and an excellent case in point is afforded by the boring put down by Messrs. Viau & Frère, at Maisonneuve, in which "good water" was struck at 450 feet which rose to within 10 or 12 feet of the surface, but the boring being continued to greater depths in the hope of obtaining gas, highly saline and sulphurous water was met with at 1,497 feet, which, mingling with that first encountered, rose to the surface and overflowed at the rate of 5,000 gallons per day.

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* Geology of Canada, p. 562.

Additional information may be looked for in the future.

Much additional information regarding these waters, bearing upon the question of their composition in relation to the depths from which they rise, will undoubtedly be accumulated as time goes on, additional wells are bored and a greater number of the waters are analyzed.

Another point on which additional information may be looked for is the question as to whether any change will be observed in the character of the water yielded by a single well as it continues to be pumped for a series of years. The only well in the district from which any information has been obtained on this point, up to the present time, is that put down by Messrs. Robert White & Co., at the Laurentian Baths. Four analyses of this water, taken at intervals during a period extending over twelve years, have been given on page 47. A consideration of these will show that, while the total amount of dissolved matter has varied considerably in different years, the relative proportions of the several salts held in solution by the water has not on the whole altered much. There is, however, on the whole, a slight falling off in the amount of sodium carbonate and a slight increase in sodium sulphate present, as the years have passed.

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*Chemical and Geological Essays, p. 157.

GENERAL CONCLUSIONS.

General conclusions.

From the examination of the available data in connection with the many wells which have been sunk on the Island of Montreal, it seems certain that there is no distinct water-bearing horizon in the form of interstratified permeable beds. The water passes through the limestone series in large amount, following underground channels which have the form of irregular fissures. These fissures no doubt result from the enlargement of joint and bedding planes or of irregular cracks in the limestone, by the solvent power of the waters passing through them. These enlarged fissures evidently form an irregular and complex system of water channels passing through the limestones, and occur at all depths below the surface hitherto reached by boring. The fact that the waters follow the courses of irregular fissures and not of well-defined porous beds is conclusively demonstrated by the very different results obtained by borings put down in the immediate vicinity of one another. As, for instance, on the property of Messrs. William Dow & Co., the C.P. R. workshops at Hochelaga, the Excelsior Woollen Mills, and elsewhere; wells affording an abundant supply of water being situated in the immediate vicinity of equally deep borings which supply little or no water. The Laurie Engine Company, having bored a hole to the depth of 700 feet without striking water, in another boring a few feet away obtained water at a depth of 300 feet. The character of the water also obtained from wells in the immediate vicinity of one another differs greatly, as well as the height to which the waters rise within the boring. A striking instance of this is afforded by the three wells at St. Laurent which were put down by the College, the Convent and Mr. Cousineau. In these, the water was struck at depths of 487, 250 and 128 feet, respectively. The water in the first stands at 13 feet and is soft and slightly sulphurous, that in the second rises to the surface and is very hard, while in the third well the water rises 13 feet above the surface and is of moderate hardness.

Water carried in fissures.

Fissures in some cases recognized in boring.

In some cases the fissures can be distinctly recognized in boring the well, the drill dropping into an open space, this open space being in some instances empty but in other cases carrying an abundant supply of water. In the case, for example, of one well put down by the Gould Cold Storage Co., as has been mentioned, the boring tool became so firmly jammed in a transverse fissure that the hole had to be abandoned.

In the wells put down by Mr. J. N. Drummond of Petite Côte and by the Montreal Milling Co., at Outremont, "breccia" and "honeycomb," respectively, were stated to form the water-bearing rock. These probably represent impure beds or fissures imperfectly cleared out, the more soluble material having been abstracted. In the case of the Laurentian Baths well on Craig street and Dr. Craik's well at Petite Côte, the water rises from shaly layers which probably represent the insoluble residue of a bed of argillaceous limestone, into which the water moving throught the fissures had here found its way.

Many details of evidence in support of the fact that the movement of the waters is through fissures will be met with in the descriptions of the various wells, already given. The accompanying graphic diagrams of the wells will show the great variations in depth at which water was struck in the wells in question, the height to which water rises in them, and in the thickness of the drift; all these having been plotted with reference to sea level.

Course of underground waters influenced by dykes.

The course of the underground waters is also without doubt in many places rendered still more irregular by the dykes and sheets of impervious igneous rock which cut through the stratified rocks in all directions.

The amount of water now pumped daily from the wells is very large and most of them are not by any means pumped to their full capacity. In fact, the capacity of many of them has never been determined, since, when found to yield sufficient for the purposes required, no determination of the maximum yield was ever attempted.

Yield of the wells on the Island of Montreal.

An inspection of the Tabular Statement of the wells, accompanying this report, will show that at a very moderate estimate the wells already bored would yield 2,500,000 gallons per diem; which is almost exactly one tenth of the daily average amount of water pumped by the Montreal Water Works for the use of the city.

The waters obtained differ greatly in character. Very many of them are soft waters of excellent quality. Others again are hard, while a few are sulphurous or highly saline. As has been shown it is impossible to predict what the character of the water obtained at any point will be, if any be obtained, for waters of very diverse characters are pumped from wells situated in the immediate vicinity of each other or indeed may be obtained from the same well as in the case of number 78. The question of the probability of obtaining water and its character, if obtained, is however discussed on page 72.

Source of the waters.

The source of the underground water is in all probability the higher portion of the plains along the flank of the Laurentian country in the northwestern part of the geological map-sheet. It is scarcely likely that very much of it is derived from the Laurentian country itself, although there is reason to believe that some of it may be. Most of it probably passed underground into the palæozoic strata along the flank of the Laurentian plateau. Here the rain water would sink into the soil which almost everywhere mantles the underlying rocks, and, passing down to the surface of these rocks, would flow along it until cracks or fissures were met with, down which it would pass. An abundant supply of water is actually obtained in many places in this district by driving pipes down into the lower portions of the drift which here constitutes the soil, and thus tapping the supplies of water passing over the surface of the underlying rock. The palæozoic plain along the foot of the Laurentian plateau may be taken as having an average elevation of about 300 feet above sea level, while the surface of the Island of Montreal is much lower. The underground waters thus move to the south under considerable head or pressure, and when the channels through which they pass are tapped by borings in the vicinity of Montreal the water rises by virtue of this pressure, in a very few cases actually reaching the surface, but in the other cases remaining at different distances below it. In only five wells on the Island does the water rise more than 200 feet above sea level; the wells in question being the Park well, the wells of Messrs. Nantel and Goyer at Côte des Neiges (where the water rises 340 feet above sea level), and the wells of Messrs. Drummond and Stewart at Petite Côte, where the water rises 225 feet above sea level. In only eleven of the wells does the water rise to the surface and in only six does it overflow. These latter are the wells at the Turkish Baths, Laurentian Baths, Montreal Cold Storage Co., M. Cousineau, Messrs. Viau Frère and Messrs. Charles Gurd & Co. It will be noticed that the five wells above mentioned, in which the water rises above the 200 feet level, are all situated on the slopes of Mount Royal, and it is doubtful in how far the drainage from the mountain itself affects them.

The water rises to the surface in only eleven of the wells.

It is just possible that the Potsdam sandstone which outcrops immediately along the edge of the Laurentian plateau carries water which subsequently rises through fissures in the limestone, and it would be very interesting if a boring sufficiently deep to tap the Potsdam sandstone were made on the Island of Montreal, in order that it might be ascertained whether this formation carries any considerable supply of water. A study of the records of the borings, however, would indicate that the water-bearing channels lie chiefly in the Trenton and Chazy limestones; the deeper wells affording but little water, or water which is very impure.

Origin of hardness in waters.

Upon its source, the kind of rock traversed and its solvent power, the presence of dissolved carbonic acid, etc., depends the character of the water in any particular well. It can be readily understood that water passing through the Potsdam sandstone or the underlying Laurentian rocks and rising in fissures through the overlying strata to the surface would probably be soft. If, on the other hand, the water has traversed the limestone or dolomite throughout its entire course, following tortuous channels, a considerable amount of lime salts might be taken into solution and the water might thus become hard or possibly impure from the presence of saline and sulphurous compounds.

Chances of obtaining water by boring.

In conclusion, it may be asked as a practical question, what the chances are of obtaining water by boring in the Island of Montreal. As has been shown it is never possible to predict with certainty that water can be secured by boring at any particular spot, but a simple calculation based on the actual results obtained by the wells (89 in number) which have up to the present time (January 1, 1904) been put down in this area, shows that the chances of obtaining a large supply of water—that is to say, more than 5,000 gallons per diem—are about 7 to 2. That is to say, water will be obtained in seven out of every nine wells that are bored; while water of potable quality and in large amount will be secured in rather more than six out of every ten trials or in about two out of every three holes. In some of these however the water will be hard.

Depth to which the boring should be carried.

A second practical conclusion which can be drawn from the results which have been presented in this Report, is that if a boring is put down and water is not obtained by the time a depth of 750 feet has been reached, it is better to abandon the hole and sink another, rather than to continue boring deeper, even if this second hole has to be put down in the immediate vicinity of the first, since it has been shown that at depths greater than this abundant supplies of good water are rarely obtained, the water (if any be found) being in the great majority of cases small in amount or too impure to be of any value.

As has been stated in the sketch of the geology of the district, the maximum thickness of the several formations of the Lower Silurian, as determined from their field relations by Sir William Logan and others, is as follows in descending order :—

Lorraine	2000	feet.
Utica	300	"
Trenton Group	600	"
Chazy	300	"
Calciferous	450	"
Potsdam	700	"
Total	4350	"

Omitting the first two, the supposed maximum thickness of the last four would be 2,050 feet. Thickness of the formations.

These determinations have not been substantiated by the complete log of the Turkish Bath well or by a study of the materials obtained from the dry well bored on the property of the Montreal Gas Co., at Hochelaga. In the case of the first mentioned well, from the fossils in the rock chips, determined by Dr. Ami, and from certain accessory chemical tests, the approximate thickness of two formations was obtained. The section in descending series gave the following :—

Pleistocene (drift)	50	feet.
Trenton Group	590	"
Chazy	785	"
Calciferous	125	"
Total	1550	"

The bottom of the Calciferous was not reached, and it is possible that some of the upper beds of the Trenton have been removed by erosion, and that the Chazy alone is represented in its entire thickness.

At the Gas Company's well, an examination of the borings obtained between the 2,200 and 2,373 feet levels showed that they were derived from the Calciferous sand-rock ; and at 2,550 feet—the bottom of the well—the Potsdam sandstone had not yet been encountered. Correlating this result with the above, and allowing 600 feet and 785 feet for the maximum thickness of the Trenton and Chazy respectively, the Calciferous would have a thickness of over 1,000 feet. This discrepancy between the determination of the thickness of the several formations as they outcrop at the surface and the results obtained from the borings can be accounted for in two ways. In the first place, faults may exist which have obscured the relation of the rocks in the field. These might easily occur and escape observation, as the strata Faults.

are almost flat and so continuously covered by the drift that the rock crops out in comparatively few places.

Formations apparently thicker on going south from Laurentian margin.

Mr. LeRoy, who has made the geological map and section which accompany this Report, has in the latter shown a fault in the line of the intrusion of Mount Royal, and it seems probable from the thickness of the Utica shale in the harbour at Montreal that a fault occurs along the east side of the Island, between the Trenton and Utica formations. This belief is strengthened by the results of a boring at Laprairie, where 1,000 feet of shale were traversed and no limestone encountered.

But it would seem in the second place that there must be, in addition to any faulting, a very considerable thickening of the several formations of the Lower Silurian as the distance from the old Archæan shore line increases.

While therefore the explanation of the phenomenon is as yet uncertain the fact remains that the limestone-dolomite series has a much greater thickness than might be expected. It is hoped that the logs of future wells may throw additional light on this very interesting anomaly.

GEOLOGICAL SURVEY OF CANADA
ROBERT BELL, M.D., Sc.D., LL.D., F.R.S., ACTING DIRECTOR.

SECTION OF MINES

ANNUAL REPORT

FOR

1901

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ASSISTANT
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1902

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No 800

To the Director,
Geological Survey of Canada.

SIR,—Herewith I beg to hand you the detailed annual report of the Section on the mineral industries of Canada for 1901. The preliminary summary statement for that year, which was completed on February 26, is of course replaced by the revised statement herein contained.

The work of the Section, as in the past, has consisted not only in the preparation of the annual report, but in the collection, recording, &c., of technical information, and in making investigations into a great variety of matters pertaining to the economic mineral resources and the mineral industries of the country, as well as in answering the numerous enquiries on these subjects constantly coming to hand.

During the summer my own time was occupied making field studies of the copper ore deposits in the Bruce mines district, and of their geological conditions of occurrence in collaboration with Mr. T. C. Denis, B. Sc. Appreciative acknowledgement is made of the important aid in the whole work of the Section rendered by Mr. J. McLeish and Mrs. W. Sparks.

Thanks are also due to those who, although too numerous to mention individually, by answering our circulars or letters, provided much valuable material. Our acknowledgments are also due to the provincial mining bureaus of Nova Scotia, Quebec, Ontario and British Columbia, as well as to the Dominion Customs and Inland Revenue departments for aid received.

I am, sir,
Your obedient servant,

ELFRIC DREW INGALL,
Mining Engineer to the Geological Survey.

Section of Mines,
November 6, 1902.

EXPLANATORY NOTES.

YEAR AND TON USED.

The year referred to throughout this report is the calendar year, except for the figures of imports, which refer to the fiscal year ending June 30. The ton is that of 2,000 pounds, unless otherwise stated.

EXPORTS AND IMPORTS

The figures given throughout the report referring to exports and imports are compiled from data obtained from the books of the Customs Department, and will occasionally show discrepancies, which, however, there are no means of correcting.

The exports and imports under the heading of each province do not necessarily represent the production and consumption of the province; e.g., material produced in Ontario is often shipped from Montreal and entered there for export, so falling under the heading, Quebec.

NOTE.—N.E.S.=Not elsewhere specified.

VALUES ADOPTED.

The values of the metallic minerals produced, as per returns to this Department, are calculated on the basis of their metallic contents at the average market price of the metal for the current year. Spot values have been adopted for the figures of production of the non-metallic minerals.

GENERAL NOTES.

As in the past, care is taken to avoid interference with private interests in the manner of publishing results, and all returns of production of individual mines are treated as confidential, unless otherwise arranged with those interested. The confidence of the mining community, thus gained, has resulted in an increasingly general response to our circulars, although to complete our data, personal application is still necessary in a small number of instances, and a yet more prompt response on the part of all applied to, will help still further towards an earlier publication of the material.

In view of criticisms of these statistics which have been made recently, and from time to time in the past, it may be well to take this opportunity to explain the working methods adopted, in order to prevent the misunderstandings which underlie such criticisms and suggestions, and to correct the impression which they might convey to the public, that the reports are in any way unreliable.

The figures given throughout the reports are based, as far as possible, upon returns obtained direct from the various operators, or from official data, and the totals have for some years been checked by comparison with railway shipments, exports, and all other available sources of information. It can be therefore fairly claimed, that they are as accurate as it is possible to make such figures.

After investigation of the subject we have, however, found that in the nature of things, export and railway figures can only be taken as approximately correct in most instances. In the case of the export figures, entries are made, as a rule, by those having no technical knowledge of mineral subtances, and in the case of the railways, but few of the shipments are actually weighed, so that car-load lots, for instance, may differ considerably from the theoretical load of the car.

The lists of operators given throughout the report are not put forward as complete in every case, only those reporting their production being included. Producers finding their names omitted are invited to communicate with this office that they may be included in the next issue.

CORRECTIONS—ALTERATIONS.

Corrections and alterations have been made throughout this report wherever they seemed to be called for, according to more complete and reliable data available since previous issues.

The tabulated statement given in the folded sheet at the beginning of the report, represents a compilation of all the similar statements found in previous reports, re-modelled and further revised wherever possible.

INTRODUCTORY.

Mineral Production of Canada.

Comparing the mineral production for 1901 with that for the previous year, we find an increase in the grand total of values of $2,207,571 equivalent to 3·42%. This is a considerable falling off from the ratios for the previous period of four years as shown in the subjoined table, a similar result being shown by the mineral industries of the neighbouring republic to the south of us.

Year.	Canada.		United States.	
	Increase per cent in Grand Total.	Production per capita.	Increase per cent in Grand Total.	Production per capita.
	p.c.	$ c.	p.c.	$ c.
1901	3·42	12·40	2·60	14·03
1900	30·06	11·99	10·10	14·02
1899	28·13	9·33	39·86	12·84
1898	34·89	7·32	10·61	9·38
1897	26·90	5·52	1·33	8·66
1896	8·79	4·40	·21	8·73
1895	....	4·09	....	8·90
1890	64·00	3·50	38·97	9·89
1886		2·23		7·76

The results shown above are to be accounted for mostly on the basis of the large falling off in the output of the gold of the Yukon district. This was inevitable if the history of all other placer districts was to be repeated in this instance. The time invariably comes when the rapid working out of the richer spots is accomplished, and the sensational features characterizing the starting of work in such a district give way to the steadier and more reliable results following on the inauguration of well organized effort; and the further stage resulting from the discovery and development of bodies of gold-bearing quartz, will it is hoped follow shortly.

MINERAL PRODUCTION OF CANADA.

A most gratifying fact is that the above mentioned falling off has been more than offset by the growth in the aggregate value of the remaining mineral products, amounting to over 15 per cent, comparing their total values for this year with similar figures for 1900.

PRODUCTS.	QUANTITY.		VALUE.	
	Increase.	Decrease.	Increase.	Decrease.
	p. c.	p. c.	p. c.	p. c.
Metallic—				
Copper	99·75		98·85	
Gold		13·54		13·54
Pig iron (from Canadian ore only)	134·83		107·85	
Pig iron (from both home and imported ores)	184·11		133·93	
Lead		17·84		18·52
Nickel	29·78		38·07	
Silver	23·97		19·16	
Non-metallic—				
Asbestus and asbestic	38·01		68 32	
Coal	11·04			9·67
Coke	132·62		89·21	
Cement	7·87			·43
Gypsum	16·54		31·33	
Natural gas				18·61
Petroleum	12·40		12·40	

On reference to the figures given above, an idea will be formed of the condition of the various mineral industries, as compared with last year. All but two of the items show increases in quantity, although in some instances a decrease appears in the value columns, owing to lower prices being realized. The lead mining and natural gas industries show a decided falling off, as does also the gold as a whole. In this latter case the proportion of decrease due to the Yukon region is somewhat modified by increases in some of the other districts. In all the remaining metal-mining industries large increases of production are recorded, more or less offset, however, in every instance except nickel, by lower prices. Large proportional increases in the figures are reported for all the non-metallic minerals except natural gas, and gypsum and asbestus brought higher prices. In coal, coke and cement, however, a falling off is shown in the aggregate values. In the coal industry this was mostly due to the lower valuation put upon Nova Scotia coal.

PROPORTIONATE VALUE OF DIFFERENT MINERAL PRODUCTS, 1901.

MINERAL PRODUCTION OF CANADA.

Products.	Contributing over 10 p. c.	Contributing between 10 and 1 p. c.	Contributing under 1 p. c.	Total.
1. Gold	36·17			
2. Coal	17·99			
3. Copper		9·14		
4. Nickel		6·89		
5. Silver		4·89		
6. Bricks (estimated)		3·59		
7. Lead		3·37		
8. Building stone (estimated)		2·47		
9. Asbestus		1·89		
10. Coke		1·84		
11. Pig Iron (from Canadian ore)		1·82		
12. Petroleum		1·51		
13. Lime (estimated)		1·25		
14. Iron ore (exported)		1·14		
15. Cement			·99	
16. Gypsum			·51	
17. Natural Gas			·51	
18. Sundry under 1 per cent			4·03	
Total	54·16	39·80	6·04	100·00

The relative importance of the various branches of the mineral industry are illustrated by the figures in the foregoing table. As usual, gold and coal are the two most important by a considerable amount. The group of metallic products is to be credited with over 63 per cent and coal and coke with nearly 20 per cent, and these two important classes together, account for over 83 per cent of the whole.

PRODUCTION BY PROVINCES, 1901.

Province.	Value of Production.	Per cent.
Nova Scotia	$ 8,360,719	12·5
New Brunswick	467,985	·7
Quebec	3,761,639	5·7
Ontario	14,351,585	21·5
Manitoba and Northwest Territories including Yukon	19,297,940	28·9
British Columbia	20,472,840	30·7
Total	66,712,708	100·0

The relative contributions of the different provinces to the grand total are set forth above. It will be seen that the falling off in the Yukon gold now gives British Columbia front rank. Western Canada is to be credited with nearly 60 per cent as against the 40 per cent contributed by the territory lying east of Lake Winnipeg.

Mineral Production of Canada.

Of the value of the mineral substances exported by Canada, over one half is represented by gold. This, with the other metallic products—copper, iron, steel, iron ore, lead, nickel—together with coal and asbestus constitute the chief exports and aggregate over 90 per cent of the whole.

Exports.

EXPORTS.

MINERALS AND MINERAL PRODUCTS OF CANADA DURING CALENDAR YEAR 1901.

Products.	Value.	Products.	Value.
Antimony ore	$ 1,643	Manufactures of metals other than iron or steel	$ 156,757
Asbestus, first class	383,756	Mica	152,553
" second class	107,471	Mineral pigments	8,233
" third class	598,091	Mineral waters	2,960
Barytes	3,820	Nickel	751,080
Bricks	5,189	Oil crude	691
Cement	1,514	Oil refined	66
Chromite	25,444	Ores unspecified	261,973
Clay, manufactures of	119	Platinum	591
Coal	4,828,811	Phosphate	[illegible]
Coke	176,980	Plumbago crude	30,535
Copper	3,404,908	" manufactures of	4,567
Feldspar	10,973	Pyrites	[illegible]
Gold	[illegible]	Salt	[illegible]
Grindstones	22,441	Sand and gravel	117,465
" rough	[illegible]	Silver	[illegible]
Gypsum crude	[illegible]	Slate	[illegible]
" ground	[illegible]	Stone unwrought	[illegible]
Iron and steel	1,887,179	" wrought	[illegible]
Iron ore	[illegible]	Other articles	[illegible]
Lead	[illegible]		
Lime	[illegible]		
Manganese ore	[illegible]	Total	[illegible]

[illegible]

[illegible] FISCAL YEAR [illegible]

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	$ [illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]		

MINERAL PRODUCTION OF CANADA.

From the foregoing table it will be seen that whilst of our exports, the products of the mine are destined for many different countries, the United States takes 95 per cent and the others comparatively insignificent amounts.

Imports.

IMPORTS.

MINERALS AND MINERAL PRODUCTS, FOR FISCAL YEAR 1900-1901.

Products.	Value.	Products.	Value.
Alum and aluminous cake.	$ 43,693	Lead, and mfrs. of........	$ 282,587
Aluminium....	8,916	Lime.....................	14,534
Anchors	19,567	Litharge.	51,944
Antimony	24,714	Lithographic stone.... ...	8,084
Arsenic	8,361	Manganese, oxide of......	8,176
Asbestus and mfrs. of. ...	50,829	Marble, and mfrs. of......	96,159
Asphaltum	67,587	Mercury........	94,564
Bells and gongs.......	56,016	Metallic alloys—	
Bismuth	828	Brass, and mfrs. of......	844,716
Blast furnace slag..... ...	3,107	Britannia metal.........	12,248
Borax	64,720	Metals, N.E.S., and mfrs. of	775,051
Bricks and tiles...........	133,343	Mineral and bituminous substances, N.E.S... ...	23,449
" fire...	418,461	Mineral and metallic pigments, paints and colours	774,922
Buhrstones.......	5,762	Mineral waters.....	71,521
Building stone and granite	112,833	Nitrate of soda, &c.. ...	29,408
Cement.........	669,839	Ores of metals, N.E.S.. .	598,016
Chalk........	11,629	Paraffine wax...........	9,639
Clays......	141,251	" candles........ .	3,588
Coal..	13,155,534	Petroleum, and products of	982,640
" tar and pitch.........	88,093	Phosphate (fertilizer).	19,977
Coke	680,138	Phosphorus......	3,438
Copper and mfrs. of.......	1,103,319	Platinum.................	20,263
Copperas	14,330	Precious stones..	740,481
Cryolite...........	2,158	Pumice	5,516
Crucibles, clay or plumbago	38,874	Salt..	373,974
Earthenware	1,114,677	Saltpetre.................	46,804
Emery..................	39,116	Sand and gravel.	42,891
Felspar, quartz, flint, &c..	12,555	Slate, and mfrs. of.. .. .	72,187
Fertilizers................	74,208	Sulphate of copper.......	73,190
Fuller's earth	3,147	Sulphur....	270,608
Gold and silver, and mfrs. of	359,646	Sulphuric acid....	5,272
Graphite, and mfrs. of....	39,019	Tin, and manufactures of..	2,338,839
Grindstones	45,176	Whiting	60,878
Gypsum, plaster of Paris, &c	6,200	Zinc, and manufactures of.	168,622
Iron and steel—		Total..........	$52,192,664
Pigs, scraps, blooms, &c.	1,055,350		
Rolled—bars, plates, &c., including chrome steel.	5,633,168		
Ferro-silicon, ferro-manganese, &c..........	38,954		
Manufactures of, machinery, hardware, &c...	17,923,320		

The above table illustrates in a rough way the needs of the community in regard to mineral substances and their products, which might possibly be met to a greater or less extent in the future with the further discovery and development of our own resources. The most prominent items are coal, whose imports amount in value to about one-quarter of the total, and manufactures of machinery, accounting for about one-third of the whole, or together adding up to about 58 per cent. The items going to make up the latter will be found *in extenso* in their appropriate connection later in the report. Their bearing is rather on the manufacturing than in connection with the mineral industries. In regard to the coal item, 61·5 per cent represents imports of anthracite of a quality of which we have as yet none in this country.

Abrasive Materials.

ABRASIVE MATERIALS.

Grindstones.

Grindstones, woodpulp stones, scythe stones, &c., have for many years been made in the eastern provinces of Canada, from the millstone grit of the Carboniferous formation, which occupies a large portion of the surface of the eastern half of the province of New Brunswick, and the northern and northwestern parts of Nova Scotia.

Owing to the cessation of work at one of the large quarries in Nova Scotia, the production of grindstone in 1901 was less than that of the previous year. The total output amounted to 4,581 tons, valued at $45,960, the decrease being 958 tons. In the province of New Brunswick, from which the greater part of the production was obtained, there was a slight increase; in fact this province has been steadily increasing its output of grindstone, &c., for the past six or seven years.

The grindstones sold are nearly all shipped in a finished condition and are worth about $10 a ton. Woodpulp stones of about 2½ tons, sell for from $40 to $45 each. At many of the quarries there is a considerable production of foundation and building stone, besides rough stone for breakwater and harbour works.

ABRASIVE MATERIALS.

Grindstones.

Statistics of production by provinces since 1886 are given in Table 1. below.

TABLE 1.

ABRASIVE MATERIALS.

ANNUAL PRODUCTION OF GRINDSTONES.

Production.

CALENDAR YEAR.	NOVA SCOTIA.		NEW BRUNSWICK.		TOTAL.		AVERAGE VALUE PER TON.
	Tons.	Value.	Tons.	Value.	Tons.	Value.	
1886	1,765	24,050	2,255	22,495	4,020	46,545	$11 58
1887	1,710	25,020	3,582	38,988	5,292	64,008	12 10
1888	1,971	20,400	3,793	30,729	5,764	51,129	8 87
1889	712	7,128	2,692	23,735	3,404	30,863	9 07
1890	850	8,536	4,034	33,804	4,884	42,340	8 67
1891	1,980	19,800	2,499	22,787	4,479	42,587	9 51
1892	2,462	27,610	2,821	23,577	5,283	51,187	9 69
1893	2,112	21,000	2,488	17,379	4,600	38,379	8 34
1894	2,128	16,000	1,629	16,717	3,757	32,717	8 71
1895	1,400	14,000	2,075	17,932	3,475	31,932	9 19
1896	1,450	14,500	2,263	18,810	3,713	33,310	8 97
1897	1,407	17,500	3,165	24,840	4,572	42,340	9 26
1898	1,422	12,350	3,513	32,425	4,935	44,775	9 07
1899	1,378	10,300	3,133	32,965	4,511	43,265	9 59
1900	1,411	12,600	4,128	40,850	5,539	53,450	9 65
1901	358	3,200	4,223	42,490	4,581	45,690	9·97

The localities where operations are being carried on have been known and worked for many years. The principal quarries are situated in the province of New Brunswick on the Bay of Chaleur at Clifton and Stonehaven; on Miramichi Bay in the vicinity of Newcastle; and along the shore of Shepody Bay in the Bay of Fundy; while in Nova Scotia the points to which attention has been chiefly directed, are at Lower Cove, Cumberland Basin and at Woodbourne, Pictou county. A large proportion of the production is exported, chiefly to the United States. Statistics of exports and imports are given in Tables 2 and 3. Almost $30,000 worth of grindstones, &c., were imported in 1901, principally into the provinces of Ontario and Quebec.

ABRASIVE MATERIALS.

Grindstones.

Exports.

TABLE 2.

ABRASIVE MATERIALS.

EXPORTS OF GRINDSTONES.

Calendar Year.	Value.	Calendar Year.	Value.
1884	$28,186	1893	21,672
1885	22,606	1894	12,579
1886	24,185	1895	16,723
1887	28,769	1896	19,139
1888	28,176	1897	18,807
1889	29,982	1898*	25,588
1890	18,564	1899*	23,288
1891	28,433	1900*	42,128
1892	23,567	1901*	29,130

* Including stone for the manufacture of grindstones.

Imports.

TABLE 3.

ABRASIVE MATERIALS.

IMPORTS OF GRINDSTONES.

Fiscal Year.		Duty.	Tons.	Value.
1880			1,044	$11,714
1881			1,359	16,895
1882			2,098	30,654
1883			2,108	31,456
1884			2,074	30,471
1885			1,148	16,065
1886			964	12,803
1887			1,309	14,815
1888			1,721	18,263
1889			2,116	25,564
1890			1,567	20,569
1891			1,381	16,991
1892			1,484	19,761
1893			1,682	20,987
1894			1,918	24,426
1895			1,770	22,834
1896			1,862	26,561
1897			1,521	25,547
1898				22,217
1899				27,476
1900				34,382
1901	Grindstones not mounted and not less than 36 inches in diameter	15 p.c.		32,943
	Grindstones N.E.S.	25 p.c.		6,125
				39,068

A list of quarry operators is appended herewith, some of whom, however, did not manufacture any grindstones during the year.

ABRASIVE MATERIALS.

Grindstones.

NOVA SCOTIA—

The Atlantic Grindstone Co., Lower cove, Cumberland county.
J. W. Sutherland, Quarry Island, Woodbourne, Pictou county.

NEW BRUNSWICK—

Henry Tower, Lower Rockport, Westmoreland county.
H. C. Read, Sackville, Westmoreland county.
A. D. Richard, Dorchester, Westmoreland county.
W. B. Deacon, Shediac, Westmoreland county.
C. E. Fish, Newcastle, Northumberland county.
J. B. Read, Stonehaven, Gloucester county.
Messrs. Lombard & Co., Clifton, Gloucester county and Boston, Mass.
R. W. Knowles, Clifton, Gloucester county.

Corundum.

Corundum.—The production of corundum in Ontario in 1900 and 1901, was as follows:—

	Quantity.	Value.
1900....................	3 tons.	$ 300
1901....................	444 "	53,115

This is almost all the result of the operations of the pioneer company in the field, the Canada Corundum Company, Ltd., Toronto. Fifty men were employed throughout the year. The company's mine, 'The Craig Mine,' is situated in the township of Raglan, Renfrew county. The present mill was greatly enlarged during 1901. It is operated both by steam and water power, has been built in a very suitable location, and is filled with the latest machinery for the crushing and separating of the mineral. It is now proposed to erect a mill with ten times the present capacity. The product is sold in Canada, the United States and Great Britain, and a large market for it is available in Germany, France, Italy, Holland, Belgium and Sweden. The Imperial Corundum Company and the Crown Corundum and Mica Company, both of Toronto, did a considerable amount of development work, the former on lot 14 and part of lot 15, concession 8, and the latter on lot 14, concession 9, township of Methuen, Peterborough county.

ABRASIVE MATERIALS.

Imports.

Statistics of imports of buhrstones, emery and pumice stones are given hereunder.

Buhrstones.

TABLE 4.

ABRASIVE MATERIALS.

IMPORTS OF BUHRSTONES.

Fiscal Year.	Value.	Fiscal Year.	Value.
1880	$12,049	1891	$ 2,089
1881	6,337	1892	1,464
1882	15,143	1893	3,552
1883	13,242	1894	3,029
1884	5,365	1895	2,172
1885	4,517	1896	2,049
1886	4,062	1897	1,827
1887	3,545	1898	1,813
1888	4,753	1899	1,759
1889	5,465	1900	1,546
1890	2,506	1901*	5,762

* Buhrstones in blocks, rough or unmanufactured, not bound up or prepared for binding into mill-stones. Duty free.

Emery.

TABLE 5.

ABRASIVE MATERIALS.

IMPORTS OF EMERY.

Fiscal Year.	Emery. *a.*	Mfrs. of Emery. *b.*
1885	$ 5,066	$ 4,920
1886	11,877	5,832
1887	12,023	4,598
1888	15,674	4,001
1889	13,565	3,948
1890	16,922	5,313
1891	16,179	6,665
1892	17,782	6,492
1893	17,762	5,606
1894	14,433	2,223
1895	14,569	7,775
1896	16,287	11,913
1897	16,318	11,231
1898	17,661	15,478
1899	21,454	22,343
1900	19,312	25,615
1901	16,311	22,190

a Emery in bulk, crushed or ground. Duty free.
b Emery wheels and manufactures of emery. Duty 25 p.c.

TABLE 6.

ABRASIVE MATERIALS.

IMPORTS OF PUMICE STONE.

ABRASIVE MATERIALS.

Imports.

Pumice Stone.

Fiscal year.	Value.
1885	$ 9,384
1886	2,777
1887	3,594
1888	2,890
1889	3,232
1890	3,003
1891	3,696
1892	3,282
1893	3,798
1894	4,160
1895	3,609
1896	3,721
1897	2,903
1898	3,829
1899	5,973
1900	5,604
*1901	5,516

* Pumice and pumice stone, ground or unground. Duty free.

ASBESTUS.

ASBESTUS.

Production.

The production of asbestus in Canada, for which the mines in the Eastern Townships, province of Quebec have become widely known, has been steadily increasing year by year since the beginning of operations about 1880. The year 1901 has witnessed a particularly large increase, the production (sales and shipments) amounting to 32,892 tons, valued at $1,248,645, an average for all grades of $37.96 per ton. In addition there was a production of the short fibred 'asbestic' of 7,325 tons, valued at $11,114 or an average of $1.52 per ton. The grand total of asbestus and asbestic for the year, therefore, amounted to 40,217 tons, valued at $1,259,759.

Prices of first grade fibre varied from $150 to $200 per ton, and of second grade, from $75 to $125 a ton. 'Thirds' and paper stock which preponderate in quantity, sold from $12 to $60 and asbestic from $1 to $3 a ton.

Asbestus.
Production.

Statistics of production, exports and imports, are given in Tables 1, 2, 3 and 4 following.

Table 1.

Asbestus.

Production.—1896 to 1901.

——	Tons.	Value.	Average Value per ton.
1896—Asbestus	10,892	$ 423,066	$ 38.84
Asbestic	1,358	6,790	5.00
	12,250	$ 429,856	$ 35.09
1897—Asbestus	13,202	$ 399,528	$ 30.26
Asbestic	17,240	45,840	2.66
	30,442	$ 445,368	$ 14.63
1898—Asbestus	16,124	$ 475,131	$ 29.46
Asbestic	7,661	16,066	2.10
	23,785	$ 491,197	$ 20.65
1899—Asbestus	17,790	$ 468,635	$ 26.34
Asbestic	7,746	17,214	2.22
	25,536	$ 485,849	$ 19.03
1900—Asbestus	21,621	$ 729,886	$ 33.76
Asbestic	7,520	18,545	2.46
	29,141	$ 748,431	$ 25.68
1901—Asbestus	32,892	$ 1,248,645	$ 37.96
Asbestic	7,325	11,114	1.52
	40,217	$ 1 259,759	$ 31.32

ASBESTUS.
Production.

TABLE 2.

ASBESTUS.

PRODUCTION, ETC.—1880 TO 1895.

Calendar Year.	Production.			Exports, Average value per ton.
	Tons (2,000 lbs.)	Value.	Average value per ton.	
		$	$ cts.	$ cts.
1880	380	24,700	65.00	Exports taken as production.
1881	540	35,100	65.00	
1882	810	52,650	65.00	
1883	955	68,750	71.98	
1884	1,141	75,097	65.80	
1885	2,440	142,441	58.37	
1886	3,458	206,251	59.64	
1887	4,619	226,976	49.14	63.25
1888	4,404	255,007	57.90	70.56
1889	6,113	426,554	69.77	64.44
1890	9,860	1,260,240	127.81	75.52
1891	9,279	999,878	107.75	70.07
1892	6,082	390,462	64.19	69.35
1893	6,331	310,156	49.02	57.24
1894	7,630	420,825	55.15	59.82
1895	8,756	368,175	42.05	56.66

TABLE 3.

ASBESTUS.

EXPORTS.

Exports.

Calendar Year.	Tons.	Value,	Average value per ton.
1892	5,380	$373,103	$69.35
1893	5,917	338,707	57.24
1894	7,987	477,837	59.82
1895	7,442	421,690	56.66
1896	11,842	567,967	47.96
1897	15,570	473,274	30.40
1898	15,346	494,012	32.19
1899	17,883	473,148	26.46
1900	16,993	693,105	39.61
1901 1st class	5,155	$363,756	$70.56
1901 2nd "	2,210	107,471	48.63
1901 3rd "	24,904	598,691	24.04
Total, 1901	32,269	1,069,918	33.16

Asbestus.

Imports.

TABLE 4.

ASBESTUS.

IMPORTS.

Fiscal Year.	Value.
1885	$ 674
1886	6,831
1887	7,836
1888	8,793
1889	9,943
1890	13,250
1891	13,298
1892	14,090
1893	19,181
1894	20,021
1895	26,094
1896	23,900
1897	19,032
1898	26,389
1899	32,607
1900	43,455
*1901	50,829

*Asbestus in any form other than crude, and all manufactures of. Duty 25 p.c.

The asbestus production in Canada is confined almost entirely to the province of Quebec, in the district of Black Lake, Thetford and Danville in the Eastern Townships. The asbestus, (or more properly chrysotile) occurs in serpentine areas, occurring at intervals along a belt of country extending from the Vermont boundary to the Gaspé Peninsula. The economic occurrences of the mineral, however are restricted to the districts mentioned above. The mineral occurs in small veins distributed throughout the rock and mining is conducted in almost every case by open quarrying, some of the workings having now attained considerable depth. The rock mined is submitted to crushing, and the asbestus is separated, sorted and graded according to the length of fibre, by the aid of special machinery.

Asbestus is also found in some serpentines of the Laurentian areas, as for example at Pointe au Chêne, in Argenteuil county, where a mill was formerly erected, but has since been removed and also in Denholm township, and at other points in the counties of Wright and Labelle,

Following is a list of firms engaged in mining asbestus :—

Bell's Asbestus Co., Ltd.—
    Geo. R. Smith, Mgr........Thetford Mines, Que.

King Bros.—
    B. Bennett, Mgr........... " " "
Johnson's Company..... .. .... " " "

ASBESTUS.

Beaver Asbestus Co., Ltd.—
  C. H. Van Nostrand........220 Broadway, New York.
Standard Asbestus Co.—
  R. T. Hopper. ....Montreal, Que.
Manhattan Asbestus Co.—
  J. J. Penhale..............Black Lake, Que.
Canadian Asbestus Co.—
  R. Stather, Secy........... " " "
Union Asbestos Mine..... ..... " " "
James Reed, M.D..............Reedsdale, Que.
A. H. Murphy..................Black Lake, Que.
Asbestus and Asbestic Co., Ltd...Danville, Que.
Brompton Lake Asbestus Co.—
  B. Greenshields............Montreal, Que.
Ottawa Asbestus Mining Co.....Ottawa, Ont.

CHROMITE.

CHROMITE

Chromite or 'chromic iron ore' was mined as usual in small quantities in the Eastern Townships, Quebec. Shipments were made from Coleraine and Black Lake stations on the Quebec Central Railway and reached a total of 1,274 tons.

In the absence of complete direct returns from producers this is the figure which has been adopted as the production for the year. The proportion of high and low grade ore in these shipments were according to Mr.Obalski* as follows :—

1st class ore, concentrates, etc.,	592	tons valued at	$9,424
2nd " "	682	"	7,320
Total...................	1274		16,744

Prices for the year averaged about $18 for high grade ore and from $10 to $12 for second grade.

Statistics of production are given in Table 1. The output practically dates from 1894 although there was a small production in the years 1886 and 1887.

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*Mining Operations in the Province of Quebec, 1901. J. Obalski.

Chromite.

Production.

Table 1.

Chromite.

Annual Production.

Calendar Year	Tons (2,000 lbs.)	Average price per ton.	Value.
		$ cts	$
1886	* 60	15 75	945
1887	38	15 00	570
1888 to 1893	no output		
1894	1,000	20 00	20,000
1895	3,177	13 00	41,300
1896	2,342	11 53	27,004
1897	2,637	12 31	32,474
1898	*2,021	12 00	24,252
1899	2,010	10 86	21,842
1900	2,335	11 56	27,000
1901	1,274	13 14	16,744

* Railway shipments.

Statistics of exports since 1885 are given in Table 2 following. Previous to 1900 the ore was all exported, during the past two years however small quantities have been shipped to the Electric Reduction Works Co., at Buckingham and used in the manufacture of ferrochrome of which latter product there was shipped from Buckingham during 1901 about 182 tons.

Table 2.

Chromite.

Exports.

Exports.

Calendar Year.	Tons.	Value.
1895	2,908	$ 42,236
1896	2,466	31,411
1897	2,106	26,254
1898	1,683	20,783
1899	1,509	19,876
1900	368	8,259
1901	2,259	25,444

A list of some of the chief producers of chromite in Canada is given hereunder.

Coleraine Mining Co.	Montreal, Que.
Coleraine Chrome Co., W. H. Lambly	Inverness, Que.
Messrs Nadeau and Topping	Black Lake, Que.
Montreal Chrome Iron Co., H. Leonard	D'Israeli, Que.
Messrs Beebe and Sons	Boston, Mass.

COAL.

COAL.

Production.

With the exception of a small output of anthracite coal from the mines situated in the Cascade coal basin of the North-west Territories, which in 1901 amounted to only 14,742 tons, the entire product in Canada consists of bituminous coal and lignite.

The chief coal-bearing areas at present worked, are the Nova Scotia coal fields in rocks of Carboniferous age, the Cretaceous coal of Vancouver Island, British Columbia and the more recently opened fields of the Crow's Nest Pass, B.C., also found in the Cretaceous rocks. Lignitic coal of good quality is mined at Lethbridge, Alberta and in the Souris river district, Assiniboia.

The production of coal in Canada is now double what it was in 1890, and over four times the output of 1880. The production in 1901 reached a total of 6,227,352 tons of 2,000 pounds (5,560,135 tons of 2,240 pounds) valued at $12,005,565, being an increase in quantity over the output of 1900 of 618,686 tons or over 11 per cent. The aggregate value of the coal mined in 1901 was somewhat less than during the previous year, owing to the high prices obtained for coal in Nova Scotia in 1900 not being maintained during the past year.

Statistics of production by provinces for 1900 and 1901, are given in Table 1 following, while in Table 2, a comparison between the two years is shown.

TABLE 1.

COAL.

PRODUCTION BY PROVINCES, 1900 AND 1901.

Province.	1900.		1901.	
	Tons.	Value.	Tons.	Value.
Nova Scotia	3,623,536	$8,088,250	4,158,068	$ 6,496,982
British Columbia	1,623,180	4,347,804	1,660,515	4,447,809
North-west Territories including Yukon	351,950	839,375	391,139	1,008,917
New Brunswick	10,000	15,000	17,630	51,857
Total	5,608,666	$13,290,429	6,227,352	$12,005,565

COAL.

Production.

TABLE 2.

COAL.

PRODUCTION. COMPARISON OF 1900 AND 1901.

Province	Increase or Decrease.			
	Tons.	Per cent.	Value. $	Per cent.
Nova Scotia	*i* 534,532	*i* 14·75	*d* 1,591,268	*d* 19·67
British Columbia....	*i* 37,335	*i* 2·30	*i* 100,005	*i* 2·30
North-west Territories including Yukon	*i* 39,819	*i* 11·13	*i* 169,542	*i* 20·20
New Brunswick.............	*i* 7,630	*i* 76·30	*i* 36,857	*i* 245·71
Dominion..	*i* 618,686	*i* 11·04	*d* 1,284,824	*d* 9·67

i Increase. *d* Decrease.

TABLE 3.

COAL.

ANNUAL PRODUCTION SHOWING THE INCREASE OR DECREASE EACH YEAR

Calendar Year.	Tons.	Value.	Average Value per Ton.	Increase (*i*) or Decrease (*d*) in Tonnage.	Incr. (*i*) or Decr. (*d*) per cent.
1886.....	2,116,653	$3,739,840	$1 77	....	....
1887.....	2,429,330	4,388,206	1 81	*i* 312,677	*i* 14·8
1888.....	2,602,552	4,674,140	1 80	*i* 173,222	*i* 7·1
1889.....	2,658,303	4,894,287	1 84	*i* 55,751	*i* 2·1
1890.....	3,084,682	5,676,247	1 84	*i* 426,379	*i* 16·0
1891.....	3,577,749	7,019,425	1 96	*i* 493,067	*i* 16·0
1892.....	3,287,745	6,363,757	1 94	*d* 290,004	*d* 8·1
1893. ...	3,783,499	7,359,080	1 95	*i* 495,754	*i* 15·1
1894. ...	3,847,070	7,429,468	1 93	*i* 63,571	*i* 1·7
1895.....	3,478,344	6,739,153	1 94	*d* 368,726	*d* 9·6
1896.....	3,745,716	7,226,462	1 93	*i* 267,372	*i* 7·7
1897.....	3,786,107	7,303,597	1 93	*i* 40,391	*i* 1·1
1898.....	4,172,582	8,222,878	1 97	*i* 386,475	*i* 10·2
1899.....	4,925,051	10,283,497	2 09	*i* 752,469	*i* 18·0
1900.....	5,608,666	13,290,429	2 37	*i* 683,615	*i* 13.9
1901.....	6,227,352	12,005,565	1 93	*i* 618,686	*i* 11·04

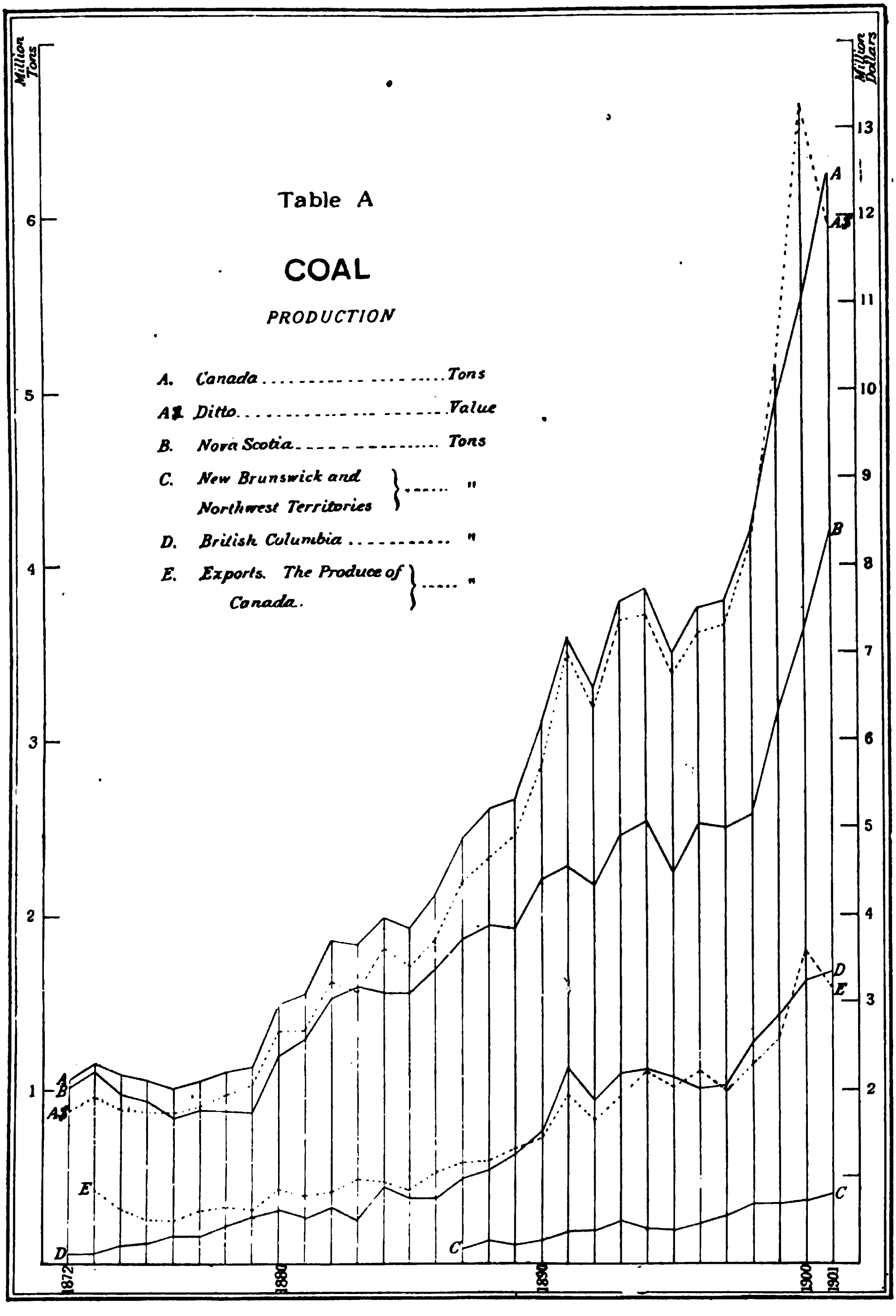

Table A

COAL

PRODUCTION

Coal.
Production

In spite of the opening up of new mines in the western provinces, the coal fields of Nova Scotia not only continue to supply the greater part of the Canadian product, nearly 67 per cent in 1901, but they have also during the past three or four years been increasing their proportion of the total output, as evidenced by the following table which shows the percentage of production to be credited to the several provinces at various periods since 1874.

Province.	1874.	1880.	1890.	1898.	1899.	1900.	1901.
	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.	p. c.
Nova Scotia	91	79	71	61·4	63·9	64·6	66·8
British Columbia	8	20	25	30·3	29·0	28·9	26·7
Northwest Territories New Brunswick.	.....	.....	4	8·3	7·1	6·5	6·5

The statistics of production since 1886, showing the increase each year and the yearly average value per ton, are given in Table 3, while statistics of exports and imports are given in Tables 4, 5, 6, 7 and 8 following. Changes in the Dominion's foreign coal trade were comparatively unimportant; exports were somewhat less than during 1900 but still larger than any other previous year. Imports of both anthracite and bituminous coal were greater than in 1900.

TABLE 4.

COAL.

EXPORTS.

Exports.

CALENDAR YEAR.	PRODUCE OF CANADA.	NOT PRODUCE.	CALENDAR YEAR.	PRODUCE OF CANADA.	NOT PRODUCE.
	Tons.	Tons.		Tons.	Tons.
1873	420,683	5,403	1888	588,627	84,316
1874	310,988	12,859	1889	665,315	89,294
1875	250,348	14,026	1890	724,486	82,534
1876	248,638	4,995	1891	971,259	77,827
1877	301,317	4,829	1892	823,733	93,988
1878	327,959	5,468	1893	960,312	102,827
1879	306,648	8,468	1894	1,103,694	89,786
1880	432,188	14,217	1895	1,011,235	96,836
1881	395,382	14,245	1896	1,106,661	116,774
1882	412,682	37,576	1897	986,130	101,848
1883	486,811	44,388	1898	1,150,029	99,189
1884	474,405	62,665	1899	1,293,169	101,004
1885	427,937	71,003	1900	1,787,777	62,776
1886	520,703	78,443	1901	1,573,661	53,894
1887	580,965	89,098			

COAL.

Exports.

TABLE 5.

COAL.

EXPORTS.—NOVA SCOTIA AND BRITISH COLUMBIA.

Calendar Year.	Nova Scotia.		*British Columbia.	
	Tons.	Value.	Tons.	Value.
1874	252,124	$647,539	51,001	$ 278,180
1875	179,626	404,351	65,842	356,018
1876	126,520	263,543	116,910	627,754
1877	173,389	352,453	118,252	590,263
1878	154,114	293,795	165,734	698,870
1879	113,742	203,407	186,094	608,845
1880	199,552	344,148	219,878	775,008
1881	193,081	311,721	187,791	622,965
1882	216,954	390,121	179,552	628,437
1883	192,795	336,088	271,214	946,271
1884	222,709	430,330	245,478	901,440
1885	176,287	349,650	250,191	1,000,764
1886	240,459	441,693	274,466	960,649
1887	207,941	390,738	356,657	1,262,552
1888	165,863	330,115	405,071	1,605,650
1889	186,608	396,830	470,683	1,918,263
1890	202,387	426,070	508,882	1,977,191
1891	194,867	417,816	767,734	2,958,695
1892	181,547	407,980	599,716	2,317,734
1893	203,198	470,695	708,228	2,693,747
1894	310,277	633,398	770,439	2,855,216
1895	241,091	534,479	728,283	2,692,562
1896	380,149	787,270	679,799	2,507,752
1897	307,128	642,754	630,341	2,221,737
1898	309,158	629,363	813,843	2,948,428
1899 †	459,260	827,941	781,809	2,947,369

*See foot-note, table 16.

†Since 1899, exports by provinces have not been published in Trade and navigation Report.

TABLE 6.

COAL.

Imports.

IMPORTS OF BITUMINOUS COAL.

Fiscal Year.	Tons.	Value.	Fiscal Year.	Tons.	Value.
1880	457,049	$1,220,761	1891	1,598,855	$4,060,896
1881	587,024	1,741,568	1892	1,615,220	4,099,221
1882	636,374	1,992,081	1893	1,603,154	3,967,764
1883	911,629	2,996,198	1894	1,359,509	3,315,094
1884	1,118,615	3,613,470	1895	1,444,928	3,321,387
1885	1,011,875	3,197,539	1896	1,538,489	3,299,025
1886	930,949	2,591,554	1897	1,543,476	3,254,217
1887	1,149,792	3,126,225	1898	1,684,024	3,179,595
1888	1,231,234	3,451,661	1899	2,171,358	3,691,946
1889	1,248,540	3,255,171	1900	2,439,764	4,310,964
1890	1,409,282	3,528,959	1901*	2,516,392	4,956,025

*Duty, 53c. per ton.

COAL.
Imports.

TABLE 7.

COAL.

IMPORTS OF ANTHRACITE COAL.

Fiscal Year.	Tons.	Value.	Fiscal Year.	Tons.	Value.
1880.........	516,729	$1,509,960	1891........	1,399,067	$5,224,452
1881.........	572,092	2,325,937	1892.........	1,479,106	5,640,346
1882.........	638,273	2,666,356	1893.........	1,500,560	6,355,285
1883.........	754,891	3,344,936	1894.........	1,530,522	6,354,040
1884.........	868,000	3,831,283	1895.........	1,404,342	5,350,627
1885.........	910,324	3,909,844	1896.........	1,574,355	5,667,096
1886.........	995,425	4,028,050	1897.........	1,457,295	5,695,168
1887.........	1,100,165	4,423,062	1898.........	1,460,701	5,874,685
1888.........	†2,138,627	5,291,875	1899.........	1,745,460	6,490,509
1889.........	1,291,705	5,199,481	1900.........	1,654,401	6,602,912
1890.........	1,201,335	4,595,727	1901*........	1,933,283	7,923,950

*Coal anthracite, and anthracite coal dust. Duty free.

†In Table 7, Imports of Anthracite Coal, a very considerable increase will be noticed in 1888 over 1887, an increase of over ninety-four per cent, the falling off again in 1889 being quite as remarkable. The average values per ton for the three years 1887, 1888 and 1889, were $4.02, $2.47 and $4.03 respectively. Although a duty of fifty cents per ton on anthracite coal was removed May 13, 1887, it is hardly thought this would account for the changes indicated, and unless some error may possibly have crept into the Trade and Navigation Report, no explanation is available.

TABLE 8.

COAL.

IMPORTS OF COAL DUST.

Fiscal Year.	Tons.	Value.	Fiscal Year.	Tons.	Value.
1880.........	3,565	$ 8,877	1891.........	60,127	$36,130
1881.........	337	666	1892.........	82,091	39,840
1882.........	471	900	1893.........	109,585	44,474
1883.........	8,154	10,082	1894.........	117,573	49,510
1884.........	12,782	14,600	1895.........	181,318	52,221
1885.........	20,185	20,412	1896.........	210,386	53,742
1886.........	36,230	36,996	1897.........	225,562	59,609
1887.........	31,401	33,178	1898.........	229,445	45,556
1888.........	28,808	34,730	1899.........	276,547	44,717
1889.........	39,980	47,139	1900.........	330,174	98,349
1890.........	53,104	29,818	1901*........	414,432	275,559

*Duty, 20 p. c., not over 13c. per ton.

An approximation to the consumption of coal in Canada, sufficiently accurate for purposes of comparison, may be made as follows, if we assume the figures of imports for the fiscal year to represent closely enough the importation during the calendar year.

COAL.

Consumption in Canada.

	Tons.	Tons.
Production Table 3.....	6,227,352	
Exports of coal, the production of Canada, Table 4.............	1,573,661	
Home consumption of Canadian coal......		4,653,691
Imports of bituminous anthracite and coal dust, Tables 6, 7 and 8	4,864,107	
Exports of coal not the production of Canada, Table 4.............	53,894	
Home consumption of imported coal..		4,810,213
Total consumption of coal in Canada, home and imported...........		9,463,904

Table 9 embodies similar calculations for each year since 1886. Therein is shown the consumption of Canadian and imported coal and the percentage of each, as well as the total consumption per capita. It will be seen that not only the total consumption, but the consumption per capita also has been steadily increasing. The total consumption in 1901 was greater than in 1900 by 1,281,452 tons or 15·6 per cent.

An interesting feature to be deduced from the above figures is the relation between the total production as given in Table 3 and the total consumption. Thus in 1901 the production amounted to 65·8 per cent of the consumption as compared with 68·5 per cent in 1900, 63·7 per cent in 1899, 66·1 per cent in 1898 and 63·9 per cent in 1897. In 1890 the proportion was 62·4 per cent and in 1886, 60·8 per cent.

COAL.

Consumption in Canada.

TABLE 9.

COAL.

CONSUMPTION OF COAL IN CANADA.

Calendar Year.	Canadian.	Imported.	Total.	Percentage Canadian.	Percentage Imported.	Consumption per capita.
	Tons.	Tons.	Tons.			Tons.
1886	1,595,950	1,884,161	3,480,111	45·9	54·1	·758
1887	1,848,365	2,192,260	4,040,625	45·7	54·3	·871
1888	2,013,925	3,314,353	5,328,278	37·8	62·2	1·137
1889	1,992,988	2,490,931	4,483,919	44·4	55·6	·946
1890	2,360,196	2,581,187	4,941,383	47·8	52·2	1·031
1891	2,606,490	2,980,222	5,586,712	46·7	53·3	1·153
1892	2,464,012	3,082,429	5,546,441	44·4	55·6	1·133
1893	2,823,187	3,110,462	5,933,649	47·6	52·4	1·198
1894	2,743,376	2,917,818	5,661,194	48·5	51·5	1·130
1895	2,467,109	2,933,752	5,400,861	45·7	54·3	1·066
1896	2,639,055	3,206,456	5,845,511	45·1	54·9	1·140
1897	2,799,977	3,124,485	5,924,462	47·3	52·7	1·143
1898	3,022,553	3,274,981	6,297,534	48·0	52·0	1·200
1899	3,631,882	4,092,361	7,724,243	47·0	53·0	1·454
1900	3,820,889	4,361,563	8,182,452	46·7	53·3	1·521
1901	4,653,691	4,810,213	9,463,904	49·1	50·9	1·761

NOVA SCOTIA.

Nova Scotia.

Detailed statistics of production of coal in this province are given in Tables 10, 11, 12, and 13. In Table 10, the output, sales and colliery consumption, are shown both in tons of 2,240 pounds and in tons of 2,000 pounds. The production shows a considerable increase over the previous year and is the largest in the history of coal mining in this province. It reached a total of 4,158,068 tons (2,000 pounds) being an increase over 1900 of 534,532 tons or nearly 15 per cent. The price of coal at shipping point, which rose to an average of $2.50 per long ton in 1900, fell off again during 1901 and averaged about $1.75 for the year. The various tables require but little comment. It will be noted that the Dominion Coal Company supplies by far the greater part of the output, over 67 per cent, being more than all the other mines of the province combined. In the table of distribution of coal sold, increased shipments to all markets are shown with the exception of New Brunswick and the United States. The consumption of coal in Nova Scotia has been increased by the operations of the Dominion Iron and Steel Company. While some small shipments have been made to Europe, these had not attained much importance before the close of the year. The future, however, would appear to hold bright prospects for an increased demand in this direction.

COAL
Nova Scotia.

TABLE 10.

COAL.

NOVA SCOTIA:—OUTPUT, SALES, COLLIERY CONSUMPTION, AND PRODUCTION.

Calendar Year.	Output, Tons, 2,240 lbs.	Sales, Tons, 2,240 lbs.	Colliery Consumption, Tons, 2,240 lbs.	Production* Tons 2,240 lbs.	Output, Tons, 2,000 lbs.	Sales, Tons, 2,000 lbs.	Colliery Consumption, Tons. 2,000 lbs.	Production* Tons, 2,000 lbs.	Price per Ton. 2,240 lbs.	Value of production.
1872	880,950	785,914	110,341	896,255	986,664	880,224	123,582	1,003,806	$1 75	$1,568,446
1873	1,051,467	881,106	108,398	989,504	1,177,643	986,839	121,406	1,108,245	1 75	1,731,632
1874	872,720	749,127	119,582	868,709	977,446	839,022	133,932	972,954	1 75	1,520,240
1875	781,165	706,795	124,110	830,905	874,905	791,610	139,003	930,613	1 75	1,454,064
1876	709,646	634,207	113,788	747,995	794,804	710,312	127,443	837,755	1 75	1,308,991
1877	757,496	687,065	98,841	785,906	848,396	769,513	110,702	880,215	1 75	1,375,339
1878	770,603	693,511	88,627	782,138	863,075	776,732	99,262	875,994	1 75	1,368,741
1879	788,271	688,624	84,787	773,411	882,863	771,259	94,961	866,220	1 75	1,353,469
1880	1,032,710	954,659	96,831	1,051,490	1,156,635	1,069,218	108,451	1,177,669	1 75	1,840,108
1881	1,124,270	1,035,014	107,888	1,142,902	1,259,183	1,159,216	120,834	1,280,050	1 75	2,000,079
1882	1,365,811	1,250,179	111,381	1,361,560	1,529,708	1,400,200	124,747	1,524,947	1 75	2,382,730
1883	1,422,553	1,297,523	111,949	1,409,472	1,593,259	1,453,226	125,383	1,578,609	1 75	2,466,576
1884	1,389,295	1,261,650	116,769	1,378,419	1,556,011	1,413,048	130,781	1,543,829	1 75	2,412,233
1885	1,352,205	1,254,510	127,624	1,382,134	1,514,470	1,405,051	142,939	1,547,990	1 75	2,418,735
1886	1,502,611	1,373,666	142,421	1,516,087	1,682,924	1,538,506	159,512	1,698,018	1 75	2,653,152
1887	1,670,830	1,519,684	139,777	1,659,461	1,871,330	1,702,046	156,550	1,858,596	1 75	2,904,067
1888	1,776,128	1,576,692	157,443	1,734,135	1,989,263	1,765,895	176,336	1,942,231	1 75	3,034,735
1889	1,756,279	1,555,107	158,131	1,713,238	1,967,032	1,741,720	177,107	1,918,827	1 75	2,998,167
1890	1,984,001	1,786,111	161,240	1,947,351	2,222,081	2,000,444	180,589	2,181,033	1 75	3,407,864
1891	2,044,784	1,849,945	174,983	2,024,928	2,290,158	2,071,938	195,981	2,267,919	1 75	3,543,624
1892	1,942,780	1,752,934	175,092	1,928,026	2,175,913	1,963,286	196,103	2,159,389	1 75	3,374,046
1893	2,223,042	1,977,543	205,425	2,182,968	2,489,807	2,214,848	230,076	2,444,924	1 75	3,820,194
1894	2,250,631	2,060,920	196,206	2,257,126	2,520,707	2,308,231	219,751	2,527,982	1 75	3,949,970
1895	1,999,756	1,793,098	193,639	1,986,737	2,239,727	2,008,270	216,875	2,225,145	1 75	3,476,790
1896	2,292,675	2,046,828	192,975	2,239,803	2,567,796	2,292,447	216,132	2,508,579	1 75	3,919,655
1897	2,340,031	2,044,672	181,716	2,226,388	2,620,835	2,290,032	203,522	2,493,554	1 75	3,896,179
1898	2,262,656	2,121,126	167,428	2,288,554	2,534,175	2,375,661	187,519	2,563,180	1 75	4,004,970
1899	2,865,443	2,633,989	177,460	2,811,449	3,209,296	2,950,067	198,755	3,148,822	2 00	5,622,898
1900	3,298,791	2,998,737	236,563	3,235,300	3,694,646	3,358,585	264,951	3,623,536	2 50	8,088,250
1901	3,821,033	3,411,127	301,434	3,712,561	4,279,557	3,820,462	337,606	4,158,068	1 75	6,496,982

* This Production is obtained by adding Sales and Colliery Consumption. For sales previous to 1872, see report of the Department of Mines Nova Scotia, 1883, page 68.

COAL.
Nova Scotia.

TABLE 11.

COAL

NOVA SCOTIA:—COAL TRADE BY COUNTIES.

CALENDAR YEAR.	CUMBERLAND.		PICTOU.		CAPE BRETON.		OTHER COUNTIES.	
	Raised.	Sold.	Raised.	Sold.	Raised.	Sold.	Raised.	Sold.
	Tons, 2,000 lbs.	Tons, 2,000 lbs.	Tons, 2,000 lbs.	Tons, 2,000 lbs.	Tons, 2,000 lbs.	Tons, 2,000 lbs.	Tons, 2,000 lbs.	Tons, 2,000 lbs.
1st quarter....	141,590	119,863	133,771	105,095	631,979	451,677	972	317
2nd "	142,557	119,224	147,954	132,863	854,195	778,440	20,352	5,312
3rd "	102,687	89,668	117,948	109,321	894,880	943,509	14,756	14,931
4th "	151,939	118,861	134,167	113,070	785,587	714,984	4,223	3,327
Total, 1901..........	538,773	447,616	533,840	460,349	3,166,641	2,888 610	40,303	23,887
" 1900..........	560,670	512,032	590,639	525,818	2,531,922	2,312,085	11 415	8,700

Coal.

Nova Scotia.

Table 12.

Coal.

Nova Scotia:—Output by Collieries during the Calendar Year, 1901.

Colliery.	Tons, 2,000 lbs.	Colliery.	Tons, 2,000 lbs.
Cumberland County.		*Victoria County.*	
Joggins	76,220	NewCampbelton	15,181
Jubilee	1,221		
Scotia	776		
Springhill	460,555		
Pictou County.		*Cape Breton County.*	
Acadia	302,683	Dominion Coal Co.	2,869,197
Marsh	2,227	Nova Scotia Steel and Coal Co.	264,516
Intercolonial	228,930	Gowrie and Blockhouse	22,905
Inverness County.		Sydney	10,023
Mabou	1.020		
Pt. Hood	24,103	Total	4,279,557

Table 13.

Coal.

Nova Scotia:—Distribution of Coal Sold.

Markets.	Calendar Years. 1900. Tons, 2,000 lbs.	1900. Per cent.	1901. Tons, 2,000 lbs.	1901. Per cent.
Nova Scotia, transported by land	576,807	17·2	757,975	19·8
" " sea	428,581	12 7	533,569	14·0
Total, Nova Scotia	1,005,388	29·9	1,291,544	33·8
New Brunswick	438,834	13·1	366,976	9·6
Prince Edward Island	69,046	2·1	78,324	2·1
Quebec	1,031,495	30·7	1,315,935	34·4
Newfoundland	107,605	3·2	124,265	3·3
United States	706,217	21·0	623,390	16·3
Other countries	....	......	20,028	·5
Total	3,358,585	100·0	3,820,462	100·0

New Brunswick.

New Brunswick.

There has been a considerable renewal of activity in coal mining in this province. Old operators have increased their output, while several new companies are in the field. The sales and shipments for 1901 have been returned as 17,630 short tons, valued at $51,857, which is a substantial increase over the operations of previous years.

The early completion of the New Brunswick Coal and Railway Company line between Newcastle and Fredericton, at present in course of construction, it is expected will result in an extensive development of the coal areas between Little river and Newcastle river in the Grand Lake district. COAL. New Brunswick.

At Dunsinane on the Intercolonial Railway in King's county some work of an exploratory character was undertaken, while at Coal Branch in Kent county a shaft was commenced on coal seams in that vicinity.

TABLE 14.

COAL.

NEW BRUNSWICK:—PRODUCTION.

Calendar Year.	Tons.	Value.	Value per ton.
1887	10,040	$ 23,607	$2 35
1888	5,730	11,050	1 93
1889	5,673	11,733	2 07
1890	7,110	13,850	1 95
1891	5,422	11,030	2 03
1892	6,768	9,375	1 39
1893	6,200	9,837	1 59
1894	6,469	10,264	1 59
1895	9,500	14,250	1 50
1896	7,500	11,250	1 50
1897	6,000	9,000	1 50
1898	6,160	9,240	1 50
1899	10,528	15,792	1 50
1900	10,000	15,000	1 50
1901	17,630	51,857	2 94

NORTH-WEST TERRITORIES: North-west Territories.

At Estevan and Coal Fields in Assiniboia, and Lethbridge, Anthracite and Canmore in Alberta, mining operations were carried on with increased vigour and enlarged output. Important developments have taken place at Frank and Blairmore to the east of the Crow's Nest Pass coal areas, and a considerable output from this district in the immediate future is probable. The product of a number of coal deposits of

COAL.

North-west Territories.

the Yukon district has also been utilized to a small extent during the past year, being sold in Dawson and vicinity.

The total product of the Territories, excluding the Yukon, for the year has been estimated at 385,275 tons, valued at $922,687 and made up as follows:

Estevan and Coal Fields	45,000	tons.
Lethbridge	217,034	"
Miscellaneous small mines	4,000	"
Anthracite and Canmore	103,241	"
Blairmore	16,000	"
Total	385,275	"

Of this amount 14,742 tons is anthracite coal, the balance bituminous and lignite.

The total sales in the Yukon are reported as 5,864 tons, valued at Dawson at $86,230.

Table 15 following, gives statistics of production in the North-west Territories, not including the Yukon:—

TABLE 15.

COAL.

NORTH-WEST TERRITORIES:—PRODUCTION.

Calendar Year.	Tons.	Value.	Value per ton.
1887	74,152	$ 157,577	$ 2 13
1888	115,124	183,354	1 59
1889	97,364	179,640	1 85
1890	128,953	198,498	1 54
1891	174,131	437,243	2 51
1892	184,370	469,930	2 55
1893	238,395	598,745	2 51
1894	199,991	488,980	2 45
1895	185,654	414,064	2 23
1896	225,868	606,891	2 69
1897	267,163	667,908	2 50
1898	340,088	825,220	2 43
1893	334,600	811,500	2 43
1900	351,950	839,375	2 38
1901	385,275	922,687	2 39

The various mines at Coal Fields and Roche Percée have been consolidated under the general management and direction of the Souris Coal Mining Co., Ltd.

At Frank, Alberta, a mine has been opened up and operated by the Canadian American Coal and Coke Co. According to Mr. Frank

COAL. North-west Territories.

B. Smith, inspector of coal mines for the North-west Territories, the seam has an average thickness of 12 feet, and the mine is capable of producing an average of 200 tons per day which within a few months was to be increased to 500 tons per day. The coal is bituminous, and is reported equal in steaming qualities to the Crow's Nest coal. The coaking quality has also been tested by the erection of six bee-hive ovens at the mine.

In the Yukon district, coal has so far been found and developed at three points, Cliff creek, Rock creek and Five Fingers.

The Cliff creek mine is located on the east side of the Yukon river, about 60 miles below Dawson, and 1½ miles back from the river. The property from which several thousand tons have been mined and shipped to Dawson and vicinity is owned by the North American Transportation and Trading Co. The deposit occurs in sandstones and shales, apparently of Laramie age, and the seam is stated to be about 15 feet thick.

The Rock creek coal mines are located on the river of the same name, about 7 or 8 miles from the Klondike river, and 18 miles from Dawson. The Alaska Exploration Company has been operating here during the winter of 1900-1901, the coal being brought out during the sleighing season. Lack of transportation facilities however, interfered and work ceased in April 1901. A number of private individuals are also said to have coal claims in this vicinity, but little has been done beyond prospecting.

Seams of coal above Five Fingers, on the Yukon river and nearly 200 miles above Dawson, were discovered by Wm. Ogilvie in 1887, and their exploitation was mentioned by him in the Annual Report of the Department of the Interior for 1900. A mine is reported to have been in operation at this point during 1901, but no records of production have been obtained.

BRITISH COLUMBIA:

British Columbia.

The coal production of this province is derived from two distinct fields viz; from the collieries on Vancouver Island and from those near the Crow's Nest Pass.

The total sales and shipments, &c., for the year 1901, were 1,660,515 tons, an increase of 2·3 per cent over the year 1900. This figure does not include the coal used in coke ovens which amounted in 1901 to 221,226 tons of 2240 lbs. or 247,773 short tons.

COAL.

British Columbia.

Statistics of output, home consumption, quantity sold for export &c., are shown in Table 16.

TABLE 16.

COAL.

BRITISH COLUMBIA :—PRODUCTION.

Calendar Year.	Output Tons, 2,240 lbs.	Home Consumption, Tons, 2,240 lbs.	Sold for Export, Tons. 2,240 lbs. ‡	PRODUCTION.*		Price per ton, 2,240 lbs	Value.
				Tons. 2,240 lbs.	Tons, 2,000 lbs.		
						$	$
1836-52..	10,000	From 1836 to 1873 inclusive, the output is taken as production.			11,200	4 00	40,000
1852-59..	25,398				28,446	4 00	101,592
1859¶...	1,989				2,228	4 00	7,956
1860.....	14,247				15,957	4 00	56,988
1861.....	13,774				15,427	4 00	55,096
1862.....	18,118				20,292	4 00	72,472
1863.....	21,345				23,906	4 00	85,380
1864.....	28,632				32,068	4 00	114,528
1865.....	32,819				36,757	4 00	131,276
1866....	25,115				28,129	4 00	100,460
1867. ..	31,239				34,988	4 00	124,956
1868.....	44,005				49,286	4 00	176,020
1869.....	35,802				40,098	4 00	143,208
1870.....	29,843				33,424	4 00	119,372
1871-2-3.	148,459				166,274	4 00	593,836
1874.....	81,547	25,023	56,038	81,061	90,788	3 00	243,183
1875.....	110,145	31,252	66,392	97,644	109,361	3 00	292,932
1876.....	139,192	17,856	†122,329	140,185	157,007	3 00	420,555
1877.....	154,052	24,311	115,381	139,692	156,455	3 00	419,076
1878.. ..	170,846	26,166	164,682	190,848	213,750	3 00	572,544
1879.....	241,301	40,294	192,096	232,390	260,277	3 00	697,170
1880. ..	267,595	46,513	225,849	272,362	305,045	3 00	817.086
1881.....	228,357	40,191	189,323	229,514	257,056	3 00	688,542
1882.....	282,139	56,161	232,411	288,572	323,201	3 00	865,716
1883.....	213,299	64,786	149,567	214,353	240,075	3 00	643,059
1884. ...	394,070	87,388	306,478	393,866	441,130	3 00	1,181,598
1885.....	365,596	95,227	237,797	333,024	372,987	3 00	999,072
1886.....	326,636	85,987	249,205	335,192	375,415	3 00	1,005,576
1887....	413,360	99,216	334,839	434,055	486,142	3 00	1,302,165
1888.....	489,301	115,953	365,714	481,667	539,467	3 00	1,445,001
1889.....	579,830	124,574	443,675	568,249	636,439	3 00	1,704,747
1890.....	678,140	177,075	508,270	685,345	767,586	3 00	2,056,035
1891....	1,029,097	202,697	806,479	1,009,176	1,130,277	3 00	3,027,528
1892	826,335	196,223	640,579	836,802	937,218	3 00	2,510,406
1893.....	978,294	207,851	768,917	976,768	1,093,980	3 00	2,930,304
1894.....	1,012.953	165,776	827,642	993,418	1,112,628	3 00	2,980,254
1895.....	939,654	188,349	756,334	944,683	1,058,045	3 00	2,834,049
1896.....	894,882	261,984	634,238	896,222	1,003,769	3 00	2,688,666
1897.....	892,296	290,310	619,860	910,170	1,019,390	3 00	2,730,510
1898....	1,136,015	374,953	752,863	1,127,816	1,263,154	3 00	3,383,448
1899.....	1,306,324	526,058	751,711	1.277,769	1,431,101	3 00	3,833,307
1900.....	1,590,178	535,084	914,184	1,449,268	1,623,180	3 00	4,347,804
1901. ...	1,691,557	568,440	914,163	1,482,603	1,660,515	3 00	4,447,809

*This production is obtained by adding 'Home Consumption' and 'Sold for Export.'

†52,935 of this amount was exported as sales without the division into the 'Home Consumption' and 'Sold for Export.'

‡The figures in the 'Sold for Export' column do not agree as they should with those given in Table 5, the only explanation being that the data in the two cases are from different sources, and it has not been possible to find out the cause of the difference.

¶Two months only.

COAL.

British Columbia.

Statistics of coal production in 1901 are given in the Annual Report of the Minister of Mines for the province as follows :

SALES AND OUTPUT FOR YEAR. Tons of 2240 lbs.	Tons.	Cwt.	Tons.	Cwt.
Sold for consumption in Canada..	413,704	18		
" export to U.S.A..................	895,197	10		
" " to other countries	18,965	15		
Total sales..................	1,327,868	03		
Used under colliery boilers &c..............	154,735	01		
Total sales and colliery consumption.........			1,482,603	04
Used in making coke.... .. ..,......			231,226	
			1,713,829	04
Stock on hand first of year.................	27,977	01		
" " last of year.................. .	5,704	17		
Difference taken from stock during the year..			22,272	04
Output of collieries for year................			1,691,557	

Statistics of labour and wages are given in the same report as follows. Number of hands employed, daily wages paid etc.

CHARACTER OF LABOUR.	UNDERGROUND.		ABOVE GROUND.		TOTAL.	
	No. of employees	Average daily wage	No. of employees	Average daily wage	No. of employees	Average daily wage
Supervision & clerical assistance....................	47	$ 4 65	40	$ 4 00	87	$ 4 32
Whites—						
Miners..................	1,739	4 00	....	....	1,739	4 00
Miners helpers...........	327	2 40	....	....	327	2 40
Labourers..................	602	2 65	213	2 50	815	2 60
Mechanics & skilled labour	64	2 85	215	3 15	279	3 00
Boys...........	132	1 50	22	1 15	154	1 30
Japanese............	28	1 40	36	1 15	64	1 30
Chinese....................	102	1 35	407	1 20	509	1 30
Totals............	3,041		933		3,974	

During the year 1901, the Vancouver Island coal mines yielded a total output of 1,312,202 long tons of coal, of which 50,458 tons were used in making coke. This is somewhat less than the output of the previous year. The export trade was less by about 55,000 tons prob-

COAL.

British Columbia.

ably due to the increased use of oil as fuel in California. The exports of Vancouver Island coal are made principally to the state of California but also to the Hawaiian islands and Alaska. Coal for use as fuel is supplied to a large extent to the Australian, Japanese and Chinese mail steamers.

The following statistics of receipts of coal in the Californian market are given as illustrating the position which British Columbia coal occupies in this market.

	1900.	1901.
	Tons, 2,240 lbs.	Tons, 2,240 lbs.
British Columbia	766,917	710,330
Australia	178,563	175,959
English and Welsh	54,099	52,270
Eastern (Cumberland and Anthracite)	17,319	27,370
Seattle (Washington)	250,590	240,574
Tacoma "	418,052	433,817
Mount Diable, Coos Bay and Tesla	160,915	143,318
Japan and Rocky Mountains (by rail)	42,673	51,147
Total	1,889,128	1,834,785

The following companies operated coal mines on Vancouver Island during 1901:—

The New Vancouver Coal Mining and Land Company, Limited, operating the Nanaimo colliery.

The Wellington Colliery Company, Limited, operating the Wellington colliery in Cranberry district, the Wellington Colliery in Comox district, and the Alexandria Colliery in Cranberry district.

The total output of the Crow's Nest Pass Coal Company in 1901 from their Coal Creek and Michel collieries was 379,355 long tons, of which 180,768 tons were used in making coke, the increase over 1900 being more than 83 per cent.

Further details relating to production and collieries working will be found in the Annual Report of the Minister of Mines for British Columbia.

Coke.

COKE.

More than twice as much coke was made in 1901 as in 1900. The inauguration of extensive iron smelting operations at Sydney, Nova

COAL.

Coke.

Production.

Scotia, employing coke as fuel, and the continued building of new coke ovens at Fernie B.C., to supply the increasing demand for fuel used in the reduction of British Columbia ores are mainly responsible for this greatly increased output. The production in 1900 amounted to 365,531 tons valued at $1,228,225, the increase in quantity over the previous year being over 132 per cent.

Statistics of production, exports and imports, are given in Tables 1, 2, 3, 4.

TABLE 1.

COKE.

ANNUAL PRODUCTION

Calendar Year.	Tons.	Value.	Value. per Ton.
1886......	35,396	$101,940	$2 88
1887......	40,428	135,951	3 36
1888......	45,373	134,181	2 96
1889......	54,539	155,043	2 84
1890	56,450	166,298	2 95
1891......	57,084	175,592	3 08
1892	56,135	160,249	2 85
1893......	61,078	161,790	2 65
1894......	58,044	148,551	2 56
1895......	53,356	143,047	2 68
1896......	49,619	110,257	2 22
1897......	60,686	176,457	2 91
1898......	87,600	286,000	3 26
1899......	100,820	350,022	3 47
1900	157,134	649,140	4 13
1901......	365,531	1,228,225	3 36

TABLE 2.

COKE.

PRODUCTION OF COKE BY PROVINCES.

Calendar Year.	Nova Scotia.		British Columbia.	
	Tons.	Value.	Tons.	Value.
		$		$
1897	41,532	90,950	19,154	85,507
1898......	48,400	111,000	39,200	175,000
1899	62,459	178,767	38,361	171,255
1900......	61,767	223,395	95,367	425,745
1901......	222,694	590,560	142,837	637,665

COAL.

Coke.

Exports.

TABLE 3.

COKE.

EXPORTS OF COKE.

Calendar Year.	Tons.	Value.
		$
1897	2,987	6,078
1898	3,774	8,394
1899	5,557	18,726
1900	41,529	131,278
1901	57,505	176,990

Imports.

TABLE 4.

COKE.

IMPORTS OF OVEN COKE.

Fiscal Year.	Tons.	Value.
		$
1880	3,837	19,353
1881	5,492	26,123
1882	8,157	36,670
1883	8,943	38,588
1884	11,207	44,518
1885	11,564	41,391
1886	11,858	39,756
1887	15,110	56,222
1888	25,487	102,334
1889	29,557	91,902
1890	36,564	133,344
1891	38,533	177,605
1892	43,499	194,429
1893	41,821	156,277
1894	42,864	176,996
1895	43,235	149,434
1896	61,612	203,826
1897	83,330	267,540
1898	135,060	347,040
1899	141,284	362,826
1900	187,878	506,839
1901 ....Duty free.	308,786	680,138

It will be seen that both the exports and imports have been increasing rapidly in amount. The exports are principally from British Columbia, over 53,000 tons having been exported from that province during the past year. The increase in imports amounted to over 64 per cent. A large portion of the imported coke is used in the iron furnaces at Hamilton and Midland, Ont. COAL. Coke.

In Nova Scotia the total quantity of coke made, was 242,996 tons, of which 222,694 tons were used or sold during the year, the balance remaining as stock on hand. Over 200,000 tons of this product was consumed at the iron blast furnaces at Sydney and New Glasgow.

The production of coke in British Columbia is given in the provincial report as follows:

Sales and Output for the Year.	Tons, 2,240 lbs.	Tons, 2,240 lbs.
Sold for consumption in Canada......	80,154	
" export to United States......	47,379	
Total sales	....	127,533
Stock on hand, first of year...... ...	3,316	
" " last "	2,864	
Diff. taken from stock during the year.	....	452
Output for year....	....	127,081

Peat.—During the past few years many companies have been organized to manufacture peat-fuel from peat bogs in the provinces of Ontario and Quebec. Some of these have met with indifferent success, while others are still in the experimental stage or developing their properties. Peat.

Sales of peat during the past two years have been reported as follows:—

	Tons.	Value.
Year 1900....................	400	$1,200
" 1901............... ...	220	660

Copper.

COPPER.

Production.

Copper production in Canada has increased from less than 19 million pounds in 1900, to over 37 million pounds in 1901. In 1886 the production amounted to but little over three and a half million pounds and was all derived from mines in the provinces of Ontario and Quebec. In 1891 it had advanced to nearly nine million pounds.

Beginning with 1894, British Columbia began to become a factor in the yearly output, although for two or three years following, the product from this province was somewhat offset by decreases in the output from Quebec. From 1896 each year, with the exception of 1899 showed a substantial increase, until in 1900 a product of 18,937,138 pounds was reached, which, as already mentioned, was almost doubled in 1901.

Although still far behind the two chief copper producing countries, the United States and Spain, this year's output places Canada pretty much on a par with the most important of the other countries producing this metal.

The production in 1901 reached a total of 37,829,019 pounds. valued at $6,096,581 or an average of 16·117 cents per pound. The fall in the price of copper did not occur until the latter part of December and affected but slightly the average price for the year.

The various provinces contributed to the output in the following proportions : British Columbia 73 per cent, Ontario 23 per cent and Quebec 4 per cent. In 1900 the proportions were British Columbia 53 per cent, Ontario 35 per cent and Quebec 12 per cent.

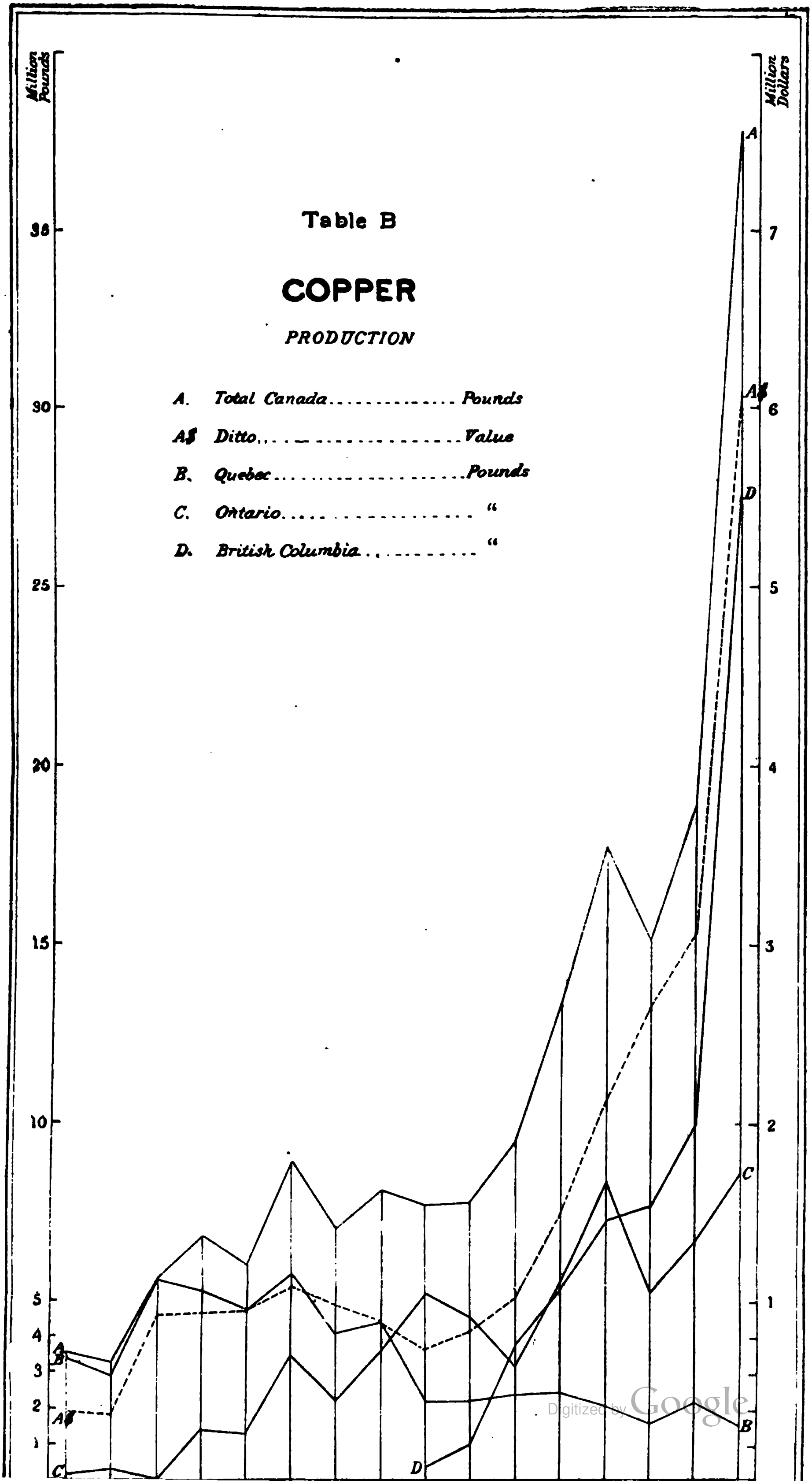

Table B

COPPER

PRODUCTION

COPPER.
Production.

TABLE 1.

COPPER.

ANNUAL PRODUCTION.*

Calendar Year.	Lbs.	Increase or Decrease.		Value.	Increase or Decrease.		Average Price per Pound.
		Lbs.	%		$	%	
				$			Cts.
1886.......	3,505,000	... .	....	385,550	....	....	11·00
1887.....	3,260,424	244,576	6·99	366,798	18,752	4·86	11·25
1888.......	5,562,864	2,302,440	70·60	927,107	560,309	152·70	16·60
1889......	6,809,752	1,246,888	22·40	936,341	9,234	0·99	13·75
1890.......	6,013,671	796,081	11·69	947,153	10,812	1·15	15·75
1891.......	8,928,921	2,915,250	48·40	1,149,598	202,445	21·37	12·87
1892......	7,087,275	1,841,646	20·62	818,580	331,018	28·79	11·55
1893......	8,109,856	1,022,381	14·40	871,809	53,229	6·50	10·75
1894.......	7,708,789	401,067	4·94	736,960	134,849	15·46	9·56
1895.......	7,771,639	62,850	·81	836,228	99,268	13·47	10·76
1896.....	9,393,012	1,621,373	20·86	1,021,960	185,732	22·21	10·88
1897.....	13,300,802	3,907,790	41·60	1,501,660	479,700	46·94	11·29
1898.......	17,747,136	4,446,334	33·43	2,134,980	633,320	42·17	12·03
1899.......	15,078,475	2,668,661	15·04	2,655,319	520,339	24·37	17·61
1900.....	18,937,138	3,858,663	25·59	3,065,922	410,603	15·46	16·19
1901......	37,827,019	18,889,881	99·75	6,096,581	3,030,659	98·84	16·117

* The production is altogether represented by the copper contained in ore, matte, &c., produced and shipped valued at the average market price for the year for fine copper in New York.

Note.—In the above table, increases are shown underlined, and decreasse in the ordinary way.

Copper.
Exports.

The exports and imports of copper as obtained from the Customs returns are shown in Tables 2, 3 and 4.

Table 2.

Copper.

Exports of Copper in Ore, Matte, etc.

Calendar Year.	Total.	
	Lbs.	Value.
		$
1885		262,600
1886		249,259
1887		137,966
1888		257,260
1889		168,457
1890		398,497
1891		348,104
1892		277,632
1893	4,792,201	269,160
1894	1,625,389	91,917
1895	3,742,352	236,965
1896	5,462,052	281,070
1897	14,022,610	850,396
1898	11,572,381	840,243
1899	11,371,766	1,199,908
1900	23,631,523	1,741,885
1901	32,488,872	3,404,908

Imports.

Table 3.

Copper.

Imports of Pigs, Old, Scrap, etc.

Fiscal Year.	Lbs.	Value.	Fiscal Year.	Lbs.	Value.
		$			$
1880	31,900	2,130	1891	107,800	10,452
1881	9,800	1,157	1892	343,600	14,894
1882	20,200	1,984	1893	168,300	16,331
1883	124,500	20,273	1894	101,200	7,397
1884	40,200	3,180	1895	72,062	6,770
1885	28,600	2,016	1896	86,905	9,226
1886	82,000	6,969	1897	49,000	5,449
1887	40,100	2,507	1898	1,050,000	80,000
1888	32,300	2,322	1899	1,655,000	246,740
1889	32,300	3,288	1900	1,144,000	180,990
1890	112,200	11,521			
1901 { Copper, old and scrap or in blocks .....Duty free				37,200	4,739
1901 { Copper in pigs or ingots.... .. .. "				914,300	147,535
Total, 1901.............				951,500	152,274

TABLE 4.

COPPER.
Imports.

COPPER.

IMPORTS OF MANUFACTURES.

Fiscal Year.	Value.
	$
1880	123,061
1881	159,163
1882	226,235
1883	247,141
1884	134,534
1885	181,469
1886	219,420
1887	325,365
1888	303,459
1889	402,216
1890	472,668
1891	563,522
1892	422,870
1893	458,715
1894	175,404
1895	251,615
1896	285,220
1897	264,587
1898	786,529
1899	551,586
1900	1,090,280

		Duty.	Pounds.	$
1901.	Copper in bolts, bars and rods, in coils, or otherwise in lengths not less than 6 feet, unmanufactured	Free.	3,102,800	521,614
	Copper, in strips, sheets or plates, not planished or coated, &c	"	2,587,400	208,477
	Copper tubing in lengths not less than 6 feet, and not polished, bent or otherwise manufactured	"	208,780	48,289
	Copper rollers, for use in calico printing, imported by calico printers for use in their own factories	"	....	15,300
	Copper and manufactures of:—			
	Nails, tacks, rivets and burrs or washers	30 p. c.	....	6,086
	Wire, plain, tinned or plated	15 "	555,847	102,664
	Wire cloth, &c	25 "	....	988
	All other manufactures of, N.O.P	30 "	....	47,627
	Total	......	....	951,045

QUEBEC:

Quebec.

There are numerous occurrences of copper ores in this province chiefly in the Eastern Townships, from which there has been a small annual production for many years. At present the output is derived almost entirely from the pyrites deposits in the county of Sherbrooke the ore being mined primarily for its sulphur contents.

Copper. Quebec.

The production in 1901 amounted to 1,527,442 lbs, valued at $246,178 and was less than that of the previous year by 692,558 lbs, or a decrease of 31 per cent.

Statistics of production since 1886 are given below.

TABLE 5,

COPPER.

QUEBEC:—PRODUCTION.

Calendar Year.	Pounds.	Value.
		$
1886	3,340,000	367,400
1887	2,937,900	330,514
1888	5,562,864	927,107
1889	5,315,000	730,813
1890	4,710,606	741,920
1891	5,401,704	695,469
1892	4,893,480	564,042
1893	4,468,352	480,348
1894	2,176,430	208,067
1895	2,242,462	241,288
1896	2,407,200	261,903
1897	2,474,970	279,424
1898	2,100,235	252,658
1899	1,632,560	287,494
1900	2,220,000	359,418
1901	1,527,442	246,178

Ontario.

ONTARIO:

The nickel-copper ores of the Sudbury district, have been the source of the greater part of the copper production in this province for the past ten or twelve years. A good deal of attention has been paid to this district during the past two years and the new works inaugurated, notably those of the Mond Nickel Company, are beginning to result in a considerably increased output. A considerable amount of development work is also in progress on the copper properties in the vicinity of Bruce Mines, Rock Lake &c.

The production in Ontario in 1901 reached a total of 8,695,831 lbs. valued at $1,401,507, being an increase in quantity over the previous year of 1,955,773 lbs. or 29 per cent, and is also the largest yearly production recorded.

COPPER.

Ontario.

Statistics of production since 1886 are given in Table 6 below.

TABLE 6.

COPPER.

ONTARIO:—PRODUCTION.

Calendar Year.	Pounds.	Value.
		$
1886	5,207,679	18,150
1887	4,576,337	36,284
1888	3,167,256	....
1889	5,500,652	201,678
1890	8,375,223	205,233
1891	5,723,324	454,129
1892	6,740,058	254,538
1893	8,695,831	391,461
1894	165,000	497,854
1895	322,524	492,414
1896	....	344,598
1897	1,466,752	621,023
1898	1,303,065	1,007,539
1899	3,527,217	1,007,877
1900	2,203,795	1,091,215
1901	3,641,504	1,401,507

BRITISH COLUMBIA.

British Columbia.

The output of copper in this province advanced from a little less than 5,000 tons in 1900 to nearly 14,000 tons in 1901, the increase being 177 per cent. Statistics of production since 1894, the output of which year was less than 200 tons, are given in Table 7 following.

TABLE 7.

COPPER.

BRITISH COLUMBIA—PRODUCTION.

Calendar Year.	Copper contained in ores, matte, &c.	Increase.		Value.
	Lbs.	Lbs.	%	
1894	324,680	....	.....	$ 31,039
1895	952,840	628,160	193	102,526
1896	3,818,556	2,865,716	301	415,459
1897	5,325,180	1,506,624	39	601,213
1898	7,271,678	1,946,498	36	874,783
1899	7,722,591	450,913	6	1,359,948
1900	9,977,080	2,254,489	29	1,615,289
1901	27,603,746	17,626,666	177	4,448,896

Copper.

British Columbia.

The output by district for the past two years was as follows :—

	1900.	1901.
	Lbs.	Lbs.
East Kootenay	2,147	3,272
West Kootenay—		
Nelson	36,929	1,599,449
Trail Creek	2,071,865	8,333,446
Yale—		
Grand Forks, Kettle River and Osoycos	5,672,177	14,511,787
Ashcroft, Kamloops	....	39,920
Coast Districts	2,193,962	3,115,872
	9,977,080	27,603,746

A comparison of the two years shows an increase in production in each separate district. The increase in the Nelson division appears especially large, owing to its small output in 1900. The Hall Mining and Smelting Company, owners of the Silver King mine, treated over 20,000 tons of ore from that property which averaged 3·8 per cent of copper, besides 16·1 ounces of silver. The same property shipped to the smelter in 1900 only about 700 tons of ore.

The ore shipped from the Rossland district in 1901 contained over four times as much copper as in the previous year, although the total quantity of ore shipped increased only 30 per cent. The copper content of these ores appears to have been somewhat variable. The average percentage of copper in the ore shipped in 1901 was 1·47 per cent, while in 1900 it was only ·476 per cent. In the years 1899, 1898 and 1897 it was 1·65 per cent, 2·35 per cent and 1·32 per cent respectively, while in each of the three preceding years it was over 2 per cent. There were only six mines in this district which shipped over 1,000 tons during the year 1901, viz. : LeRoi, LeRoi No. 2, Rossland, Great Western Mines, Ltd., Centre Star, War Eagle, and Iron Mask.

Up to 1899 productive operations in the Boundary district had been almost altogether confined to the mining of free-milling gold ore at Camp McKinney. In 1901, however, several copper properties in the district which had been undergoing extensive development during the previous few years commenced shipment, and the total output for that year from all the metal mines was 103,426 tons of ore, with a copper

COPPER.

British Columbia.

content of 5,672,177 pounds. In 1901 the output increased to 396,210 tons of ore, containing 14,511,787 pounds of copper, or over 50 per cent of the total copper output of the province. "For years it has been recognized as a fact that this district contained tremendously large bodies of ore, but it has also been admitted that the values of such ores approached so near that line which divides profit from loss that it has been a very serious question as to just which side of the line they would finally be placed. The question was one entirely dependent upon the economies which could be brought about in mining and smelting, and in the handling of a large output. It is authoritatively stated that certain of the larger properties have reduced the cost of mining to about $1 per ton, and the cost of matting the ore to from $1.35 to $1.50 per ton. On such figures as these there is a fair margin of profit on most of the ores of the district, and it is a matter of much importance to this section that such results have been obtained, as it renders of value many deposits at present unworked. At the same time it must be recognized that such low working costs are only possible after the expenditure of immense amounts of capital and by treating a large tonnage.

As in the Rossland district, the output has been derived from a few mines; in fact three properties, the Old Ironside and Knob Hill group, the Mother Lode and the B. C. contributed over 90 per cent of the total output of ore.

The increase in the production of copper in the Coast district amounted to over 42 per cent. "In addition to the Van Anda Smelter on Texada island in the Nanaimo mining division, which has been in operation for some years and has been fully described in previous reports, two new smelters are in course of erection on Vancouver Island, both in the Victoria mining division, viz. : The Tyee Copper Company's smelter at Ladysmith and the Northwestern Smelting and Refining Co.'s smelter at Crofton.

"*Crofton Smelter.*—The Northwestern Smelting and Refining Co.'s smelter is being constructed at Osborne bay, on the east coast of Vancouver island, and here the townsite of Crofton has been laid out. The smelter will treat the ore from the Lenora and other properties, and a line of narrow gauge railway is being built from the mine referred to, to Osborne bay.

The ore bins have a capacity of 1,600 tons, and a trestle railway has been laid over the top of these for convenience in unloading the

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*Report of the Minister of Mines, British Columbia, 1901 p. 935.

COPPER.

British Columbia.

ore cars. From the bins, the ore goes to the crusher and sampling building, and is thence discharged into the furnace ore bins, from which it is taken to the furnace on hand cars. The plant consists briefly of: Three 200 h. p. boilers; one 500 h. p. Corliss engine; one 450 ton water-jacketed furnace; one 65 ton water-jacketed furnace; one Bessemer converter. The main flue will be 200 feet long and 12 feet wide, communicating with a large expansion chamber where the dust settles, and from which the gases will enter the brick smoke stack, 12 feet in diameter and 125 feet high.

"The initial capacity of the smelter will be 400 to 500 tons per day, but the plant is being built with a view to allow of the treatment of 1,250 tons per day. A wharf has been built extending 750 feet into the bay.

"*Tyee Smelter.*—The Tyee Copper Company's smelter is in course of construction at Ladysmith on Oyster harbour, and is designed to treat the ore from the Tyee mine and other properties.

"The smelter is expected to be in operation by September 1, 1902. The plant will consist briefly, of a 150 ton water-jacketed furnace, a complete sampling plant, the bins having a storage capacity of 1,600 tons, an 80 horse-power Corliss engine, and an 80 horse-power tubular boiler. The smelter shed is 80 by 60 feet, and the engine-room 50 by 70 feet, with ample space for further extension.

"The ore from the sampler goes direct to the roast piles, and after burning, to the bins at the rear of the smelter. The slag will be shotted with water and flumed into the lagoon. Grading has been done for considerable extension. The converter plant will not be installed at present, but foundations will be put in so that this may be done at any time."

GRAPHITE.

GRAPHITE.

Graphite was mined in Canada in 1901 in the provinces of New Brunswick, Quebec and Ontario and the total output of crude ore was 2,210 tons, valued at $38,780. 350 tons of this was milled at Buckingham, producing some 200 tons of the finished product. The value of the crude ore ranged from $12 to $20 per ton.

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*Report of the Minister of Mines, British Columbia, 1901 p. 1122.

Statistics of production since 1886 are given in Table 1 below.

GRAPHITE.
Production.

TABLE 1.

GRAPHITE.

ANNUAL PRODUCTION.

Calendar Year.	Tons.	Value.
1886	500	$4,000
1887	300	2,400
1888	150	1,200
1889	242	3,160
1890	175	5,200
1891	260	1,560
1892	167	3,763
1893	nil.	nil.
1894*	3	223
1895	220	6,150
1896	139	9,455
1897	436	16,240
1898	....	13,698
1899	1,130	24,179
1900	1,922	31,040
1901	2,210	38,780

* Exports.

The exports and imports of graphite are shown in Tables 2 and 3.

TABLE 2.

GRAPHITE.

EXPORTS.

Exports.

Calendar Year.	Value.	Calendar Year.	Value.
1886	$ 3,586	1894	$ 223
1887	3,017	1895	4,833
1888	1,080	1896	9,480
1889	538	1897	4,325
1890	1,529	1898	13,098
1891	72	1899	22,490
1892	3,952	1900	46,197
1893	38	1901	35,102

		Cwt.	
1901	Crude	23,880	$30,535
	Manufacturers of	....	4,567
			$35,102

Graphite.

Imports.

Table 3.

Graphite.

Imports of Raw and Manufactured Graphite.

Fiscal Year.		Plumbago.	Manufactures of plumbago.	
			Black-lead.	Other Manufactures.
1880		$1,677	$18,055	$2,738
1881		2,479	26,544	1,202
1882		1,028	25,132	2,181
1883		3,147	21,151	2,141
1884		2,891	24,002	2,152
1885		3,729	24,487	2,805
1886		5,522	23,211	1,408
1887		4,020	25,766	2,830
1888		3,802	7,824	22,604
1889		3,546	11,852	21,789
1890		3,441	10,276	26,605
1891		7,217	8,292	26,201
1892		2,988	13,560	23,085
1893		3,293	16,595	23,051
1894		2,177	17,614	16,686
1895		2,586	13,922	21,988
1896		2,865	18,434	19,497
1897		1,406	17,863	20,674
1898		1,862	19,638	32,653
1899		4,979	21,334	36,490
1900		4,437	22,078	38,440
	Duty.			
1901 Plumbago, not ground, &c.	10 p.c.	$2,357		
Black-lead	25 "		$25,646	
Plumbago, ground and manufactures of N.E.S.	25 "			$11,016
Crucibles, clay or plumbago				38,874
Total, 1901		$2,357	$25,646	$49,890

In New Brunswick, the Marble Cove Mine, near Fairville Station, the product of which is used in the manufacture of paint, was continued in operation by the Canada Paint Co., of Montreal.

Comparatively little work was done in graphite mining in Quebec during the year. The Calumet Graphite Co. did some work on lots 16A in range II, and 16B in range III, of the township of Grenville and shipped the ore to Jersey City. At Buckingham the North American Graphite Co., put through their mill a quantity of ore from the Black Donald mine in Ontario, as well as some local ore.

GRAPHITE.

The Ontario Graphite Company continue to operate the Black Donald mine in Brougham township, Renfrew county, Ontario, with increased output. This company has hitherto shipped the ore in its crude form to United States buyers, but a mill is now in course of erection and the year 1902 will probably witness the manufacture of graphite goods at this mine.

GYPSUM.

GYPSUM.
Production.

Probably the most important item to record in the working of the gypsum deposits in Canada in 1901, is the commencement of active operations in Manitoba, at Gypsumville, at the head of Portage bay, Lake Manitoba. The development of these properties was referred to in the report of this Section for 1900, and during the past year several hundred tons have been mined and milled. This is doubtless but the beginning of an industry that will rapidly grow, as the population of the province increases and the value of the product becomes known. The total product of gypsum in Canada in 1901, including all grades of product was 293,799 tons, valued at $340,148, being an increase over the output of the previous year of 41,698 tons, or 16·5 per cent in quantity, and $81,139 or 31·3 per cent in value. The greater part of the product is crude gypsum and is chiefly derived from the old workings in Hants county, Nova Scotia and Hillsborough, New Brunswick.

Statistics of production, exports and imports are given in the following tables:—

Production 1897.	Tons.	Value.	Value per ton.
		$	$ c.
Crude gypsum...........................	228,416	187,918	0.82
Calcined and land plaster................	1,956	4,753	2.43
Plaster of Paris and terra alba...........	9,319	51,860	5.62
Total........	239,691	244,531	1·02

GYPSUM.

Production.

Production 1898.	Tons.	Value.	Value per ton.
		$	$ c.
Crude gypsum	208,061	174,445	0.84
Calcined and land plaster	1,583	4,574	2.89
Plaster of Paris and terra alba	9,612	53,496	5.57
Total	219,256	232,515	1.06

Production 1899.	Tons.	Value.	Value per ton.
		$	$ c.
Crude gypsum	233,819	198,831	0 85
Calcined and land plaster	717	2,246	3.13
Plaster of Paris and terra alba	10,030	56,252	5.61
Total	244,566	257,329	1.05

Production 1900.	Tons.	Value.	Value per ton.
		$	$ c.
Crude gypsum	240,970	200,323	0 83
Calcined and land plaster	1,523	4,806	3 15
Plaster of Paris and terra alba	9,608	53,880	5 60
Total	252,101	259,009	1 02

Production 1901.	Tons.	Value.	Value per ton.
		$	$ c.
Crude gypsum	280,286	236,877	0·84
Calcined and land plaster	3,139	14,574	4·64
Plaster of Paris and terra alba	10,374	88,697	8·55
Total	293,799	340,148	1·16

GYPSUM.
Production.

TABLE 1.

GYPSUM.

ANNUAL PRODUCTION.

Calendar Year.		Tons.	Value.	Average price per ton.
1886		162,000	$178,742	$ 1 10
1887		154,008	157,277	1 02
1888		175,887	179,393	1 01
1889		213,273	205,108	0 96
1890		226,509	194,033	0 86
1891		203,605	206,251	1 01
1892		241,048	241,127	1 00
1893		192,568	196,150	1 02
1894		223,631	202,031	0 90
1895		226,178	202,608	0 89
1896		207,032	178,061	0 86
1897		239,691	244,531	1 02
1898		219,256	232,515	1 06
1899		244,566	257,329	1 05
1900		252,101	259,009	1 02
1901	Nova Scotia	170,100	136,947	0 80
	New Brunswick	121,595	189,709	1 56
	Ontario	1,504	5,692	3 78
	Manitoba	600	7,800	13 00
Total, 1901		293,799	340,148	1 16

TABLE 2.

GYPSUM.

ANNUAL PRODUCTION BY PROVINCES.

CALENDAR YEAR.	NOVA SCOTIA.		NEW BRUNSWICK.		ONTARIO.		MANITOBA.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
		$		$		$		$
1887	116,346	116,346	29,102	29,216	8,560	11,715		
1888	124,818	120,429	44,369	48,764	6,700	10,200		
1889	165,025	142,850	40,866	49,130	7,382	13,128		
1890	181,285	154,972	39,024	30,986	6,200	8,075		
1891	161,934	153,955	36,011	33,996	5,660	18,300		
1892	197,019	170,021	39,709	65,707	4,320	5,399		
1893	152,754	144,111	36,916	41,846	2,898	10,193		
1894	168,300	147,644	52,962	48,200	2,369	6,187		
1895	156,809	138,929	66,949	63,839	2,420	4,840		
1896	136,590	111,251	67,137	59,024	3,305	7,786		
1897	155,572	121,754	82,658	118,116	1,461	4,661		
1898	132,086	106,610	86,083	121,704	1,087	4,201		
1899	126,754	102,055	116,792	151,296	1,020	3,978		
1900	138,712	108,828	112,294	145,850	1,095	4,331		
1901	170,100	136,947	121,595	189,709	1,504	5,692	600	7,800

Gypsum.

Exports.

Table 3.

Gypsum.

Exports of Crude Gypsum.

Calendar Year.	Nova Scotia.		New Brunswick.		Ontario.		Total.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
1874	67,830	$ 68,164	....	....	......	....	67,830	$ 68,164
1875	86,065	86,193	5,420	$ 5,420	......	....	91,485	91,613
1876	87,720	87,590	4,925	6,616	120	$ 180	92,765	94,386
1877	106,950	93,867	5,030	5,030	......	....	111,980	98,897
1878	88,631	76,695	16,335	16,435	489	675	105,455	93,805
1879	95,623	71,353	8,791	8,791	579	720	104,993	80,864
1880	125,685	111,833	10,375	10,987	875	1,240	136,935	124,060
1881	110,303	100,284	10,310	15,025	657	1,040	121,270	116,349
1882	133,426	121,070	15,597	24,581	1,249	1,946	150,272	147,597
1883	145,448	132,834	20,242	35,557	462	837	166,152	169,228
1884	107,653	100,446	21,800	32,751	688	1,254	130,141	134,451
1885	81,887	77,898	15,140	27,730	525	787	97,552	106,415
1886	118,985	114,116	23,498	40,559	350	538	142,833	155,213
1887	112,557	106,910	19,942	39,295	225	337	132,724	146,542
1888	124,818	120,429	20	50	670	910	125,508	121,389
1889	146,204	142,850	31,495	50,862	483	692	178,182	194,404
1890	145,452	139,707	30,034	52,291	205	256	175,691	192,254
1891	143,770	140,438	27,536	41,350	5	7	171,311	181,795
1892	162,372	157,463	27,488	43,623	......	....	189,860	201,086
1893	132,131	122,556	30,061	36,706	......	....	162,192	159,262
1894	119,569	111,586	40,843	46,538	......	....	160,412	158,124
1895	133,369	125,651	56,117	67,593	......	....	189,486	193,244
1896	116,331	109,054	64,946	77,535	......	....	181,277	186,589
1897	122,984	116,665	66,222	80,485	......	....	189,206	197,150
1898	99,215	93,474	70,399	81,433	......	....	169,614	174,907
1899	104,795	99,984	96,831	108,094	*½	12	201,626	208,090
1900	....	....	....	....	......	....	188,262	201,912
1901	....	....	....	....	......	....	236,247	231,594

*Exported from British Columbia.

Table 4.

Gypsum.

Exports of Ground Gypsum.

Calendar Year.	Nova Scotia.	New Brunswick.	Ontario.	Total.
	$	$	$	$
1890	....	....	....	105
1891	....	....	....	588
1892	....	....	....	20,255
1893	....	....	....	22,132
1894	2,124	17,930	....	20,054
1895	3,364	18,827	42	22,233
1896	1,270	19,246	751	21,267
1897	1,655	5,024	84	6,763
1898	1,548	4,900	....	6,448
1899	205	7,898	20	8,123
1900	....	....	....	19,834
1901	....	....	....	15,337

GYPSUM.
Imports.

TABLE 5.

GYPSUM.

IMPORTS OF GYPSUM, ETC.

Fiscal Year.	Crude Gypsum.		Ground Gypsum.		Plaster of Paris.	
	Tons.	Value.	Pounds.	Value.	Pounds.	Value.
1880	1,854	$3,203	1,606,578	$ 5,948	667,676	$ 2,376
1881	1,731	3,442	1,544,714	4,676	574,006	2,864
1882	2,132	3,761	759,460	2,576	751,147	4,184
1883	1,384	3,001	1,017,905	2,579	1,448,650	7,867
1884	....	3,416	687,432	1,936	782,920	5,226
1885	1,353	2,354	461,400	1,177	689,521	4,809
1886	1,870	2,429	224,119	675	820,273	5,463
1887	1,557	2,492	13,266	73	594,146	4,342
1888	1,236	2,193	106,068	558	942,338	6,662
1889	1,360	2,472	74,390	372	1,173,996	8,513
1890	1,050	1,928	434,400	2,136	693,435	6,004
1891	376	640	36,500	215	1,035,605	8,412
1892	626	1,182	310,250	2,149	1,166,200	5,595
1893	496	1,014	140,830	442	552,130	3,143
1894	....	1,660	23,270	198	422,700	2,386
1895	603	960	20,700	88	259,200	1,619
1896	1,045	848	64,500	198	297,000	2,000
1897	....	772	45,000	123	969,900	4,489
1898	1,147	1,742	35,700	293	329,600	2,025
1899	325	692	33,900	338	496,300	3,120
1900	77	958	6,300	69	849,100	6,492
1901	286	1,125	*65,400	1,097	502,200	3,978

*Equivalent to 218 barrels.

Crude gypsum, duty free. Ground gypsum, duty 15%. Plaster of Paris, duty 12½c. per 100 lbs.

IRON.

IRON.

Production of iron ore.

Iron Ore.—The production of iron ore in Canada in 1901 was 313,646 tons, as compared with 122,000 tons produced the previous year. The increase was therefore 191,646 tons or 157 per cent. This large increase is due almost entirely to the extensive operations at the Helen mine, Michipicoten, Ontario, as the output of the other iron producing districts remained much the same as during the past year or two.

In the province of Nova Scotia, statistics of whose production are given in Tables 1 and 2 following, the output during the past five years has been considerably less than during the previous 10 or 15

IRON.

Production of iron ore.

years. With the opening up and development of the extensive and easily worked deposits on Bell island, Newfoundland, it has been found more economical to use these ores in the Nova Scotia furnaces with a result of a temporary decline in the local production of ore.

In Quebec, bog iron ores have been used in the furnaces at Drummondville and Radnor, as in the past, in the manufacture of charcoal, pig-iron, and the production has not varied much from 15,000 to 20,000 tons per annum in the last 15 years.

The production of iron ore in Ontario has increased from a little over 25,000 tons in 1899 to over 272,000 tons in 1901. This is due, as before mentioned, to the opening up and development of large bodies of hematite ore at Michipicoten, Lake Superior. Previous to 1899, production in this province was practically confined to the districts traversed by the Kingston and Pembroke Railway and the Central Ontario Railway. The development of the Helen mine, however, by the Lake Superior Power Company, has resulted in a rapidly increasing output which is shipped to several furnaces within the province, as well as exported to the United States.

There is a small yearly production of iron ore in British Columbia, used chiefly for fluxing purposes in the smelting of the other metalliferous ores of the province :—

TABLE 1.

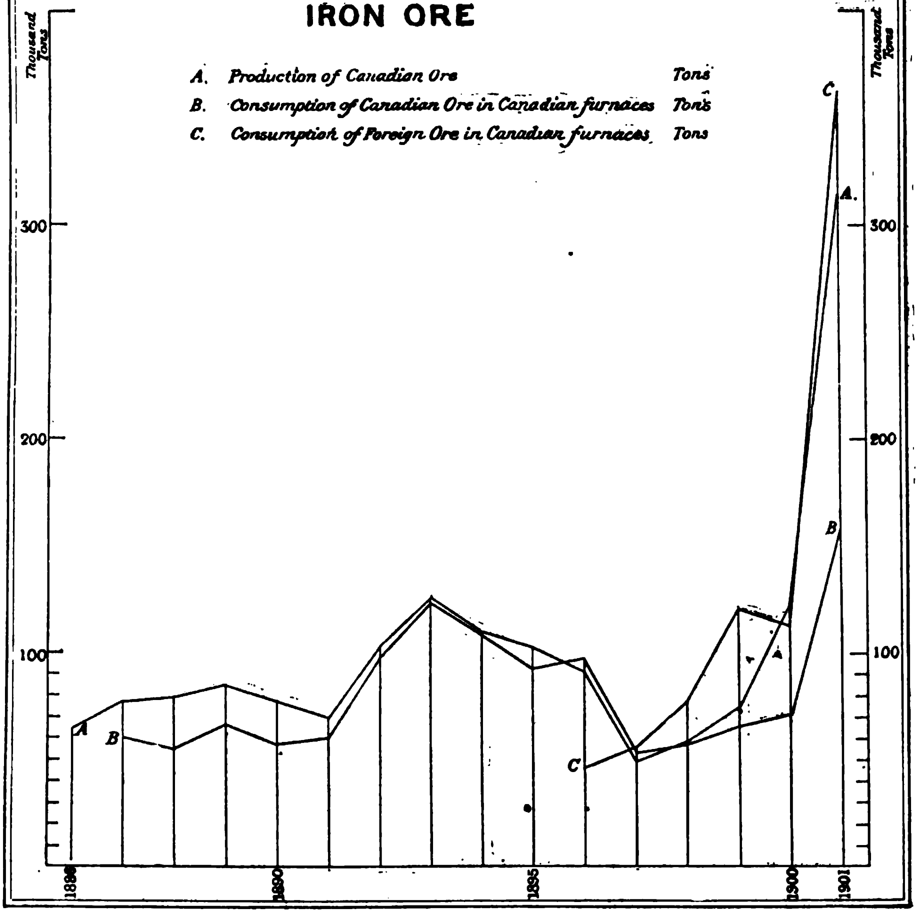
IRON.

PRODUCTION OF ORE BY PROVINCES.

Calendar Year.	Nova Scotia.	Quebec.	Ontario.	British Columbia.	Total.
	Tons.	Tons.	Tons.	Tons	Tons.
1886	44,388	....	16,032	3,941	64,361
1887	43,532	13,401	16,598	2,796	76,330
1888	42,611	10,710	16,894	8,372	78,587
1889	54,161	14,533	....	15,487	84,181
1890	49,206	22,305	....	....	76,511
1891	53,649	14,380	....	950	68,979
1892	78,258	22,690	....	2,300	103,248
1893	102,201	22,076	....	1,325	125,602
1894	89,379	19,492	....	1,120	109,991
1895	83,792	17,783	....	1,222	102,797
1896	58,810	17,630	15,270	196	91,906
1897	23,400	22,436	2,770	2,099	50,705
1898	19,079	17,873	21,111	280	58,343
1899	28,000	19,420	25,126	2,071	74,617
1900	18,940	19,000	82,950	1,110	122,000
1901	18,619	15,489	272,538	7,090	313,646

Table C

IRON ORE



IRON.

Nova Scotia.

TABLE 2.

IRON.

NOVA SCOTIA:—ANNUAL PRODUCTION OF ORE
(Previous to 1886).

Calendar Year.	Tons.
1876	15,274
1877	16,879
1878	36,600
1879	29,889
1880	51,193
1881	39,843
1882	42,135
1883	52,410
1884	54,885
1885	48,129

TABLE 3.

IRON.

EXPORTS OF IRON ORE.

Exports.

Calendar Year.	Tons.	Value.
		$
1893	2,419	7,590
1894	....	21,294
1895	1,571	3,909
1896	1,033	1,911
1897	403	811
1898	182	278
1899	4,145	9,538
1900	5,527	13,511
1901	306,199	762,283

TABLE 4.

IRON.

EXPORTS OF IRON ORE.

Fiscal Year.	Tons.	Value.	Fiscal Year.	Tons.	Value.
		$			$
1879	3,562	7,530	1891	14,648	32,582
1880	30,524	76.474	1892	7,707	36,935
1881	44,677	114,850	1893	7,811	26,114
1882	43,835	135,463	1894	1,859	9,026
1883	44,914	138,775	1895	2,315	5,743
1884	25,308	66,549	1896	14	35
1885	54,367	132,074	1897	1,320	2,492
1886	7,542	23,039	1898	260	402
1887	23,345	71,934	1899	1,849	4,968
1888	13,544	39,945	1900	4,327	7,689
1889	24,752	60,289	1901	58,401	150,657
1890	13,811	31,376			

IRON.
Pig iron.

TABLE 5.
IRON.
PIG IRON PRODUCTION : CONSUMPTION OF ORE, FUEL, &C.

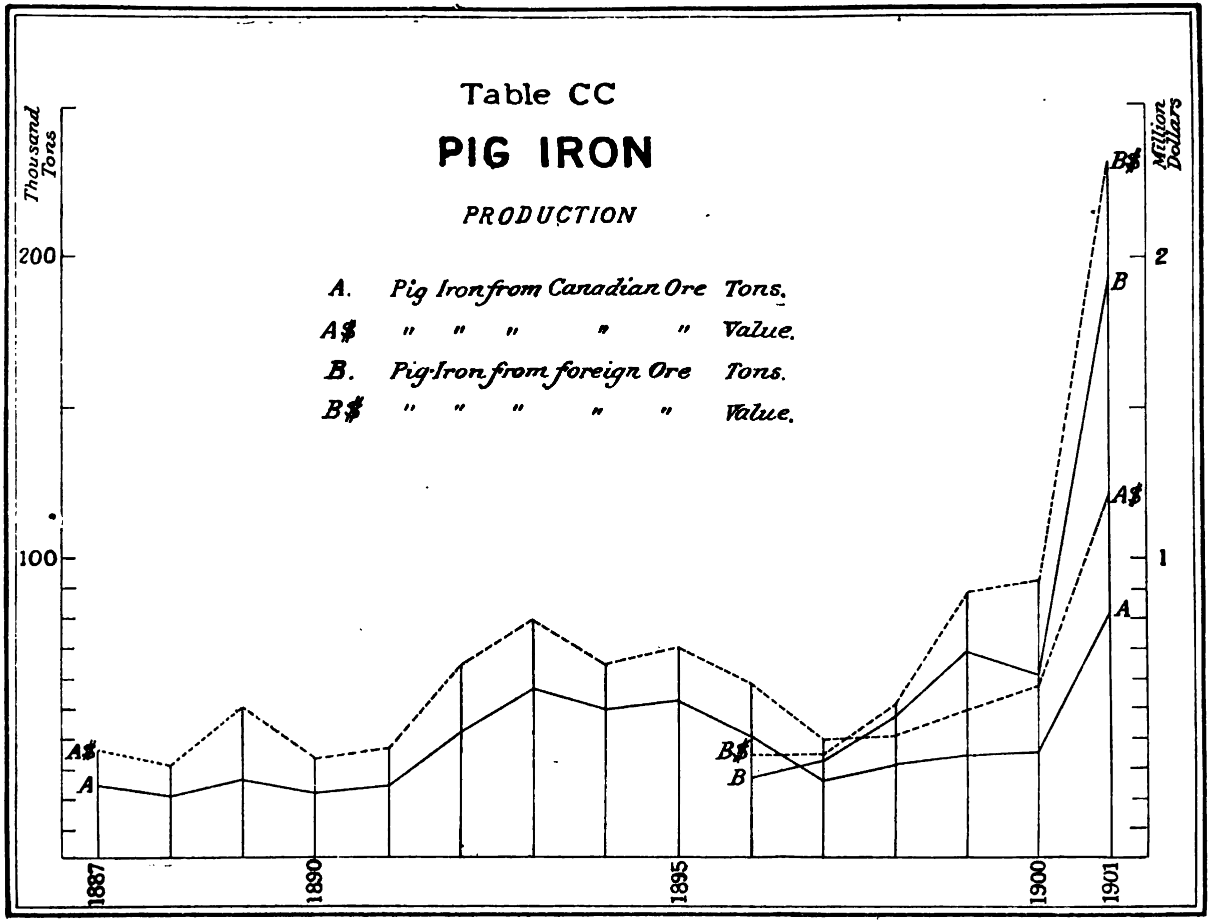
CALENDAR YEAR.	IRON ORE CONSUMED.		FUEL CONSUMED.						FLUX CONSUMED.		PIG IRON MADE.		
			Charcoal.		Coke.		Coal.						
	Tons.	Value.	Bushels.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.	Value per ton.
		$		$		$		$		$		$	$
1887..............	60,434	130,808	940,400	48,593	30,248	89,123	3,333	5,877	17,171	17,500	24,827	366,192	14 75
1888..............	54,956	102,343	804,286	41,800	28,031	82,986	2,197	4,709	16,857	16,533	21,799	313,235	14 37
1889..............	65,670	126,064	755,800	41,568	33,289	94,791	3,044	6,525	22,122	21,909	25,921	499,872	19 28
1890..............	57,304	117,880	589,860	29,493	32,832	97,659	1,241	2,638	18,478	18,361	21,772	331,688	15 23
1891..............	60,935	130,955	441,812	22,091	30,626	98,402	2,170	2,868	11,377	11,546	23,891	368,901	15 44
1892..............	96,948	250,966	1,121,365	78,291	50,882	152,311	1,740	1,797	22,967	21,687	42,443	637,421	15 02
1893..............	124,053	296,979	1,302,720	90,976	58,711	163,849	6,621	13,539	27,797	27,519	55,947	790,283	14 13
1894..............	108,871	223,861	1,173,970	53,958	52,373	142,303	7,653	14,571	35,101	34,347	49,967	646,447	12 94
1895..............	93,208	218,336	789,561	31,582	48,540	139,475	3,089	5,396	31,586	29,922	52,454	696,440	13 28
1896..............	(a) 96,560	200,887	756,600	32,256	(a) 48,660	106,939	1,407	2,288	37,462	36,140	67,268	924,129	13 74
	(b) 46,300	100,205			(b) 33,990	109,253							
1897..............	(a) 53,658	131,705	1,031,800	43,230	(a) 35,800	71,600	....	....	31,273	30,258	58,007	738,701	12 73
	(b) 55,722	138,504			(b) 27,810	94,553							
1898..............	(a) 57,881	151,760	836,400	41,820	(a) 31,952	63,904	....	....	33,913	31,153	77,015	912,395	11 85
	(b) 77,107	213,165			(b) 50,407	158,783							
1899..............	(a) 66,384	216,322	1,928,025	87,858	(a) 44,844	134,532	....	....	51,826	44,286	102,940	1,377,306	13 38
	(b) 120,650	402,860			(b) 64,648	193,944							
1900..............	(a) 71,341	184,191	1,799,737	82,408	(a) 45,021	180,084	....	....	52,966	39,332	96,575	1,501,698	15 55
	(b) 113,042	351,382			(b) 59,345	255,892							
1901..............	(a) 156,613	544,144	1,835,736	100,978	(a) 205,796	539,328	2,039	6,117	169,399	183,162	274,376	3,512,923	12 80
	(b) 361,010	846,398			(b) 115,367	497,386							

(a) Canadian. (b) Foreign.

Table CC

PIG IRON

PRODUCTION



IRON.

Pig iron and Steel.

Pig Iron and Steel.—The successful operation of the recently constructed iron furnaces in Sydney, N.S., and Midland Ontario, is evidenced by the largely increased production of pig iron in 1901. From an output in 1900 of 96,575 tons valued at $1,501,698, the production of pig iron has advanced in 1901 to a total of 274,376 tons valued, at $3,512,923. The quantity of ore entering into this year's product was 156,613 tons mined in Canada and 361,010 tons imported from Newfoundland, the United States and Cuba, or a total of 517,623 tons. Of the total product of pig iron 18,048 tons or about 6·5 per cent was charcoal iron and the balance, 286,328 tons, made with coke as fuel.

Owing to its relatively higher price, the charcoal iron constituted 8·5 per cent of the total value. In 1900 the charcoal iron constituted 18 per cent by weight and 21 per cent by value of the whole.

Before 1896, the ores used in Canadian furnaces were derived entirely from Canadian mines. Beginning with that year, however, imported ores, chiefly from the United States and Newfoundland, began to be used, the imported ore in 1901 amounting to nearly 70 per cent of the total used.

In the tabulated statement showing the mineral production of Canada, the production of pig iron from Canadian ore only, is given. This has been arrived at by separating the total production at each furnace into two classes, viz.: pig iron from Canadian ore, and pig iron from imported ore, the separation being made on the basis of the Canadian and imported ore entering into the production of pig iron at each respective furnace. The production for the past six years, separated in this way, has been as follows:

Calendar Year.	Pig iron from Canadian ore.	Pig iron from imported ore.
	Tons.	Tons.
1896	40,720	26.548
1897..........	26,200	31,807
1898.................. ..	30,553	46,462
1899......................	34,244	68,699
1900.................	35,387	61,188
1901........	83,100	191,276

IRON.

Pig iron and Steel.

There were nine furnaces in blast for varying periods during the year owned by six companies. The Dominion Iron and Steel Company had three furnaces in operation at Sydney, the Canada Iron Furnace Company, two furnaces, one at Radnor Forges and one at Midland, and the Nova Scotia Steel and Coal Company, John McDougall & Co., The Deseronto Iron Co., and the Hamilton Steel and Iron Co., one furnace each. The total daily capacity of the furnaces in operation was over 1,500 tons.

Three companies had steel plants in operation during the year; the Nova Scotia Steel and Coal Co., New Glasgow, N.S., the Canada Switch and Spring Co, Montreal, operating a Bessemer converter of two tons capacity but having completed before the close of the year the installation of a 15 ton open hearth furnace, and the Hamilton Steel and Iron Company. 41,948 tons of steel ingots, castings, &c., were made. The steel plants of the Dominion Iron and Steel Company, at Sydney, and The Lake Superior Power Company, at Sault St. Marie, were not yet completed at the close of the year, but have since been placed in operation.

Bounties.

Bounties—

Bounties on iron and steel made in Canada were provided for by the Dominion Government in 1897 (chapter 6 of 60-61 Victoria, Statutes of Canada) as follows :—

On steel ingots manufactured from ingredients of which not less than 50 per cent of the weight thereof consists of pig iron made in Canada	$3.00	per ton
On puddled iron bars manufactured from pig iron made in Canada	3.00	"
On pig iron manufactured from ore—		
On the proportion produced from Canadian ore	3.00	"
On the proportion produced from foreign ore.	2.00	"

The Act further provided that the above mentioned bounties should cease on April 23, 1902. In 1899, an Act was passed, extending the time for payment of bounties to June 30, 1907, and changing the rates in a manner providing for a gradual extinguishment of the bounties. Under the new regulations the bounties will be as follows, the classes of product being the same as those adopted in the Act of 1897 :—

IRON.

Bounties.

Period.	On steel ingots, puddled iron bars, and pig iron from Canadian ore.	On pig iron from foreign ore.
	Per ton.	Per ton.
Up to April 23, 1902	$ 3.00	$ 2.00
From April 23, 1902, to June 30, 1903	2.70	1.80
" July 1st, 1903 to June 30, 1904	2.25	1.50
" " 1904 to June 30, 1905	1.65	1.10
" " 1905 to June 30, 1906	1.05	0.70
" " 1906 to June 30, 1907	0.60	0.40

It is also provided that no bounty shall be paid on steel ingots made from puddled iron bars manufactured in Canada.

The payments by the Dominion Government on account of iron and steel bounties during the fiscal year ending June 30, 1901, were as follows, the figures having been compiled from the Auditor General's Report for 1901.

BOUNTIES ON PIG IRON.

Company.	On Pig Iron from Canadian Ore.		On Pig Iron from Imported Ore.		Total Bounties.
	Tons.	Bounties.	Tons.	Bounties.	
		$ c.		$ c.	$ c.
Canada Iron Furnace Co...					
Radnor Forges, Que....	5,463·945	16,391 83	111·565	223 13	75,784 31
Midland, Ont..........	18,948·100	56,844 30	1,162·525	2,325 05	
Deseronto Iron Co......	54·000	162 00	13,653·000	27,306 00	27,468 00
Dom. Iron and Steel Co....	....	... .	27,643·695	55,287 39	55,287 39
Electric Reduction Co......	391·000	1,173 00	....	....	1,173 00
Hamilton Steel and Iron Co.	15,033·160	45,099 48	38,678·070	77,356 14	122,455 62
John McDougall & Co.....	793·150	2,379 46	....	....	2,379 46
N. Scotia Steel and Iron Co.	9,897·295	29,691 88	18,509·705	37,019 41	66,711 29
	50,580·650	151,741 95	99,758·560	199,517 12	351,259 07

BOUNTY ON PUDDLED IRON BARS.

Company.	Tons.	Bounty.
		$ c.
Hamilton Steel and Iron Co	5,567 695	16,703 09

IRON.
Bounties.

BOUNTY ON STEEL INGOTS.

Company.	Tons.	Bounty.
		$ c.
Hamilton Steel and Iron Co	9,436 985	28,310 96
Nova Scotia Steel Co	23,915 595	71,746 78
	33,352 580	100,057 74

Table 6 following, illustrates the extent of the foreign trade of the country in regard to iron and steel products and machinery, &c., made therefrom. While the figures show a considerable falling off during the year in the export of hardware, castings N.E.S. and scrap iron and steel, they show on the other hand a very large increase in the exports of pig iron.

TABLE 6.

IRON.

Exports.

EXPORTS OF IRON AND STEEL GOODS. THE PRODUCT OF CANADA.

Calendar Year 1901.		Quantity.	Value.
			$
Stoves	No	694	7,438
Sewing Machines	„	837	18,279
Machinery, N.E.S	$		470,136
Hardware, N.E.S	„		95,213
Steel and Manufactures of	„		416,796
Castings, N.E.S	„		67,140
Scrap Iron and Steel	Cwt	194,353	168,438
Pig Iron	Tons	57,650	593,739
Total			1,837,179

The Canadian consumption of iron and steel products is illustrated in the following tables Nos. 7, 8, 9, 10a, 10b, and 11. The first three of these deal with the cruder forms of the metal, the next two with the manufactured articles wholly or largely composed of iron and steel, whilst the last table summarises all the preceeding ones. They all cover the fiscal year ending, June 30, 1901.

A general summary of the tables shows a total import of iron and steel goods of over 400,000 tons, and this leaves out of consideration a number of items the value of which only, and not the quantity is given.

IRON.
Imports.

TABLE 7.

IRON.

IMPORTS OF IRON, PIG, SCRAP, &C.

Fiscal Year.	Pig Iron.		Charcoal Pig Iron.		Old and Scrap Iron.		Wrought Scrap and Scrap Steel.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.	Tons.	Value.
		$		$		$		$
1880	(a) 23,159	371,956	....	....	928	14,042	....	....
1881	(a) 43,630	715,997	....	....	584	8,807	....	....
1882	56,594	811,221	6,837	211,791	1,327	20,406	....	....
1883	75,295	1,085,755	2,198	58,994	709	7,776	....	....
1884	49,291	653,708	2,893	66,602	3,136	44,223	....	....
1885	42,279	545,426	1,119	27,333	3,552	46,275	....	....
1886	42,463	528,483	3,185	60,086	10,151	158,100	....	....
1887	46,295	554,388	3,919	77,420	17,612	220,167	(b) 79	1,086
	Pig Iron, &c. (c)							
	Tons.	Value.						
		$						
1888	48,973	648,012	....	....	....	....	23,293	297,496
1889	72,115	864,752	....	....	....	....	26,794	335,090
1890	87,613	1,148,078	....	....	....	....	47,846	678,574
1891	81,317	1,085,929	....	....	....	....	43,967	652,842
1892	68,918	886,485	....	....	....	....	32,627	433,695
	Pig Iron.		Charcoal Pig Iron.		Cast Scrap Iron.			
	Tons.	Value.	Tons.	Value.	Tons.	Value.		
		$		$		$		
1893	56,849	682,209	5,944	84,358	729	9,317	45,459	574,809
1894	42,376	483,787	2,906	34,968	78	771	30,850	369,682
1895	(d) 31,637	341,259	2,780	31,171	643	4,347	23,390	244,388
1896	(d) 36,131	394,591	917	11,726	93	741	13,607	157,996
1897	(d) 25,766	291,788	2,936	35,373	238	1,362	7,903	93,541
1898	(d) 37,186	382,103	2,250	23,533	1,559	13,251	(e) 48,903	534,577
1899	(d) 44,261	452,911	(f) 1,955	19,123	(f) 2,378	22,594	(e) 28,352	301,268
1900	(d) 49,767	811,490	(f) 1,816	38,736	(f) 13,747	150,681	(e) 38,753	638,505
1901	(d) 35,293	548,033	(f) 490	7,121	(f) 4,499	51,032	(e) 24,773	242,189

(a) Comprises pig-iron of all kinds.

(b) From May 13 only.

(c) These figures appear in Customs reports under heading 'Iron in pigs, Iron kentledge and cast scrap-iron.'

(d) Includes iron kentledge. Duty $2.50 per ton.

(e) Scrap iron and scrap steel, old, and fit only to be remanufactured, being part of, or recovered from, any vessel wrecked in waters subject to the jurisdiction of Canada. Duty free.

Iron or steel scrap, wrought, being waste or refuse, including punchings, cuttings and clippings of iron or steel plates or sheets, having been in actual use, crop ends of tin plate bars, blooms and rails, the same not having been in actual use. Duty $1 per ton.

(f) Duty $2.50 per ton.

IRON.

Imports.

TABLE 8.

IRON.

IMPORTS OF FERRO-MANGANESE, &C.

Fiscal Year.	Tons.	Value.
*1887	123	$ 1,435
*1888	1,883	29,812
*1889	5,868	72,108
*1890	696	18,895
*1891	2,707	40,711
*1892	1,311	23,930
*1893	529	15,858
*1894	284	9,885
†1895	164	5,408
†1896	652	12,811
†1897	426	9,233
†1898	1,418	22,516
†1899	1,160	22,539
†1900	1,149	39,064
†1901 (Duty, 5 p.c.)	1,512	38,954

*These amounts include :—ferro-manganese, ferro-silicon, spiegel, steel bloom ends, and crop ends of steel rails, for the manufacture of iron or steel.

†Ferro-silicon, spiegeleisen and ferro-manganese.

TABLE 9.

IRON.

IMPORTS : IRON IN SLABS, BLOOMS, LOOPS AND PUDDLED BARS, &C.

Fiscal Year.	Cwt.	Value.	Fiscal Year.	Cwt.	Value.
1880	195,572	$244,601	1891	41,567	38,931
1881	111 666	111,374	1892	64,397	56,186
1882	203,888	222,056	1893	65,269	58,533
1883	258,639	269,818	1894	50,891	45,018
1884	252,310	264,045	1895	78,639	67,321
1885	312,329	287,734	1896	128,535	110,757
1886	273,316	248,461	1897	56,560	48,954
1887	522,853	421,598	1898	162,891	122,426
1888	110,279	93,377	1899	124,311	103,198
1889	80,383	67,181	1900	255,145	362,463
1890	15,041	45,923	1901*	234,925	206,975

*Iron or steel ingots, cogged ingots, blooms, slabs, billets, puddled bars, and loops or other forms, N.O.P., less finished than iron or steel bars, but more advanced than pig-iron, except castings. Duty $2 per ton.

IRON.
Imports.

TABLE 10a.

IRON.

IMPORTS OF IRON AND STEEL GOODS.

Fiscal Year, 1901.	Duty.	Quantity.	Value.
			$
Bar iron or steel rolled, whether in coils, bundles, rods or bars, comprising rounds, ovals, squares and flats and rolled shapes, N.O.P. .... Cwt.	$7 per ton.	267,293	448,419
Castings, iron or steel, in the rough, N.E.S. $	25 %	....	164,866
Canada plates, Russia iron, flat galvanized iron or steel sheets, terne plates and rolled sheets of iron or steel coated with zinc, spelter or other metal, of all widths or thicknesses, N.O.P. .... Cwt.	5 "	316,513	758,389
Iron or steel bridges or parts thereof, iron or steel structural work, columns, shapes or sections drilled, punched, or in any further stage of manufacture than as rolled or cast, N.E.S .... "	35 "	143,010	378,976
Malleable iron castings and iron or steel castings, N.E.S. .... "	25 "	3,180	14,442
Mould boards, or shares or plough plates land sides and other plates for agricultural implements, cut to shape from rolled plates of steel but not moulded, punched, or otherwise manufactured .... "	5 "	30,883	116,569
Iron or steel railway bars or rails of any form, punched or not punched, N.E.S., for railways, which term for the purposes of this item shall include all kinds of railways, street railways and tramways, even although the same are used for private purposes only, and even although they are not used or intended to be used in connection with the business of common carrying of goods or passengers .... Tons.	30 "	4,947	142,590
Railway fish-plates and tie plates .... "	$8 per ton.	4,618	165,960
Rolled iron or steel angles, tees, beams, channels, joists, girders, zees, stars or rolled shapes, or trough, bridge, building, or structural rolled sections, or shapes not punched, drilled or further manufactured than rolled, N.E.S., and flat eye bar blanks not punched or drilled .... Cwt.	10	298,105	460,548
Rolled iron or steel hoop, band, scroll or strip, 8 inches or less in width, No. 18 gauge and thicker, N.E.S. .... "	$7 per ton.	29,618	53,278
Rolled iron or steel hoop, band, scroll or strip, thinner than No. 18 gauge, N.E.S. "	5 %	35,565	77,276
Rolled iron or steel angles, tees, beams, channels, girders and other rolled shapes or sections, weighing less than 35 lbs. per lineal yard, not punched, drilled or further manufactured than rolled, N.O.P. "	$7 per ton.	129,361	200,343
Rolled iron or steel plates or sheets, sheared or unsheared, and skelp iron or steel, sheared or rolled in grooves, N.E.S. .... "	$7 "	73,109	122,883
Carried forward	....	....	3,104,539

IRON.

Imports.

TABLE 10*a*—*Continued.*

IRON.

IMPORTS OF IRON AND STEEL GOODS.

Fiscal Year, 1901.	Duty.	Quantity.	Value.
			$
Brought forward..................	.. ..	....	3,104,539
Rolled iron or steel plates, not less than 30 inches in width and not less than ¼ inch in thickness, N.O.P............... Cwt.	$10 per ton	210,036	290,960
Rolled iron or steel sheets No. 17 gauge and thinner, N.O.P...... .... „	5 „	130,317	347,640
Rolls of chilled iron or steel... .... „	30 „	3,147	10,177
Skelp iron or steel, sheared or rolled in grooves, imported by manufacturers of wrought iron or steel pipe for use only in the manufacture of wrought iron or steel pipe in their own factories............. „	5 „	182,457	251,524
Swedish rolled iron and Swedish rolled steel nail rods under half an inch in diameter for the manufacture of horse-shoe nails.. „	15 „	16,628	38,375
Switches, frogs, crossings and intersections for railways.... .... „	30 „	3,075	17,301
Steel—chrome steel.. ... . „	15 „	1,871	11,549
Steel plate, universal mill or rolled edge bridge plates imported by manufacturers of bridges....... .... „	10 „	63,571	87,598
Steel in bars, bands, hoops, scroll or strips, sheets or plates, of any size, thickness or width when of greater value than 2½c. per lb., N.O.P. .... „	5 „	125,803	415,036
Hoop iron not exceeding ⅜ of an inch in width and being No. 25 gauge and thinner, used for the manufacture of tubular rivets „	Free.	44,343	65,301
Iron or steel beams, sheets, plates, angles, knees and cable chains for wooden, iron, steel, or composite ships or vessels...... „	„	103,112	292,958
Locomotive and car wheel tires of steel, in the rough.............................. „	„	23,173	70,116
Steel for saws and straw cutters cut to shape, but not further manufactured..... .... „	„	15,482	131,262
Crucible sheet steel, 11 to 16 gauge, 2½ to 18 inches wide, imported by manufacturers of mower and reaper knives for manufacture of such knives in their own factories .... „	„	2,040	9,366
Steel of No. 20 gauge and thinner, but not thinner than No. 30 gauge, for the manufacture of corset steels, clock springs and shoe shanks imported by the manufacturers of such articles for the exclusive use in the manufacture thereof in their own factories.......... .. .. „	„	2,662	9,739
Steel valued at 2½ cents per lb. and upward, imported by the manufacturers of skates, for use exclusively in the manufacture thereof in their own factories...... .... „	„	2,376	10,365
Carried forward....................	....	....	5,163,806

IRON.

Imports.

TABLE 10a—*Concluded.*

IRON.

IMPORTS OF IRON AND STEEL GOODS.

Fiscal Year, 1901.	Duty.	Quantity.	Value.
			$
Brought forward……………………	…………	…………	5,163,806
Steel, under ½-inch in diameter, or under ½ inch square, imported by the manufacturers of cutlery, or of knobs, or of locks, for use exclusively in the manufacture of such articles in their own factories…… Cwt.	Free.	2,337	4,781
Steel, No. 12 gauge and thinner, but not thinner than No. 30 gauge, for the manufacture of buckle clasps, bed fasts, furniture casters and ice creepers, imported by the manufacturers of such articles, for use exclusively in the manufacture thereof in their own factories…………… "	"	657	1,433
Steel of No. 24 and 17 gauge, in sheets sixty-three inches long, and from 18 inches to 32 inches wide, imported by the manufacturers of tubular bow sockets for use in the manufacture of such articles in their own factories……………………… "	"	2,754	4,764
Steel for the manufacture of bicycle chains, imported by the manufacturers of bicycle chain for use in the manufacture thereof in their own factories……………… "	"	374	1,640
Steel for the manufacture of files, augers, auger bits, hammers, axes, hatchets, scythes, reaping hooks, hoes, hand rakes, hay or straw knives, windmills and agricultural or harvesting forks imported by the manufacturers of such or any of such articles for use exclusively in the manufacture thereof in their own factories … "	"	62,581	138,816
Steel springs for the manufacture of surgical trusses imported by the manufacturers for use exclusively in the manufacture thereof in their own factories……… "	"	475	1,264
Barbed fencing wire of iron and steel. …. "	"	142,535	316,664
Total……………………………	…………	…………	5,633,168

IRON.
Imports.

TABLE 10 *b*.

IRON.

IMPORTS OF IRON AND STEEL GOODS.

Fiscal Year, 1901.		Duty.	Quantity.	Value.
				$
Agricultural implements, N.E.S., viz:				
Binding attachments	No.	20 %	....	31,081
Cultivators	"	20 "	1,939	16,038
Drills, grain seed	"	20 "	1,499	31,092
Farm, road or field rollers	"	25 "	83	2,049
Forks, pronged	"	25 "	7,178	4,584
Harrows	"	20 "	3,760	47,862
Harvesters, self binding and without binders	"	20 "	7,888	828,118
Hay tedders	"	25 "	366	8,839
Hoes	"	25 "	26,337	3,013
Horse rakes	"	20 "	5,310	104,075
Knives, hay or straw	"	25 "	438	174
Knives, edging	"	25 "	13	107
Lawn mowers	"	35 "	1,028	5,367
Manure spreaders	"	20 "	157	5,101
Mowing machines	"	20 "	13,092	426,084
Ploughs	"	20 "	10,184	147,485
Post hole diggers	"	25 "	212	197
Potato diggers	"	25 "	41	1,297
Rakes, N.E.S	"	25 "	7,797	1,585
Reapers	"	20 "	1,003	57,681
Scythes and snaths, sickles or reaping hooks	Doz.	25 "	3,333	10,551
Spades and shovels and spade and shovel blanks, and iron or steel cut to shape for the same	"	35 "	4,048	21,130
Weeders	No.	20 "	388	457
All other agricultural implements, N.E.S.	$	25 "	....	132,193
Anvils and vises	"	30 "	....	16,325
Cart or wagon skeins or boxes	Lbs.	30 "	94,822	3,705
Springs, axles, axle bars, N. E. S., and axle blanks and parts thereof of iron or steel, for railway or tramway or other vehicles	Cwt.	35 "	32,612	63,728
Butts and hinges, N.E.S.	$	30 "	....	20,212
Cast iron pipe of every description	Cwt.	$8 per ton	31,439	50,223
Chains, coil chains, chain links and chain shackles of iron or steel 5·16 of an inch in diameter and over	"	5 %	51,260	95,183
Chain, malleable sprocket or link belting, for binders	$	20 "	....	15,070
Chains, N.E.S	"	30 "	....	40,182
Tacks, shoe	Lbs.	35 "	60,321	5,533
Cut tacks, brad sprigs, or shoe nails, double pointed, and other tacks of iron and steel, N.O.P	"	35 "	115,888	9,813
Engines, locomotives for railways, N.E.S.	No.	35 "	67	497,401
Fire engines	"	35 "	2	2,854
Fire extinguishing machines	"	35 "	18,143	22,511
Steam engines and boilers	"	25 "	686	370,153
Fittings, iron or steel, for iron and steel pipe	Lbs.	30 "	3,975,318	203,089
Carried forward		....	....	3,302,142

TABLE 10b—*Continued.*

IRON.

Imports.

IMPORTS OF IRON AND STEEL GOODS.

Fiscal Year, 1901.		Duty.	Quantity.	Value.
				$
Brought forward		....	....	3,302,142
Forgings of iron or steel, of whatever shape or size, or in whatever stage of manufacture, N.E.S., and steel shafting, turned, compressed or polished, and hammered iron or steel bars or shapes, N.O.P	Lbs.	30 %	2,097,696	72,107
Hardware, viz:				
Builders', cabinet-makers', upholsterers', harness-makers', saddlers' and carriage hardware, including currycombs and horse boots, N.E.S	$	30 "	....	542,149
Horse, mule and ox shoes	"	30 "	....	11,709
Locks of all kinds	"	30 "	....	127,423
Machines and machinery, &c.:				
Fanning mills	No.	25 "	102	2,184
Grain crushers	"	25 "	42	482
Windmills	"	25 "	452	20,583
Ore crushers and rock crushers, stamp mills, cornish and belted rolls, rock drills, air compressors, cranes, derricks and percussion coal cutters	$	25 "	....	82,513
Portable machines:				
Fodder or feed cutters	No.	25 "	24	5,355
Horse powers	"	25 "	26	2,142
Portable engines	"	25 "	75	57,417
Portable saw mills and planing mills	"	25 "	2	1,087
Threshers and separators	"	25 "	157	41,654
All other portable machines	"	25 "	1,099	27,123
Parts of above articles	$	25 "	....	24,031
Sewing machines and parts of	No.	30 "	10,392	203,075
Slot machines	"	25 "	208	9,116
Machines, type-writing	"	25 "	1,749	102,584
All other machinery composed wholly or in part of iron or steel, N.O.P	$	25 "	....	3,569,643
Nails and spikes, composition and sheathing nails	Lbs.	15 "	15,314	2,521
Nails and spikes, wrought and pressed, trunk, clout, coopers, cigar box, Hungarian horseshoe and other nails, N.E.S.	"	30 "	280,221	11,832
Nails and spikes, cut, and railway spikes	"	½c. per lb.	2,018,609	47,061
Nails, wire of all kinds, N.O.P	"	⅗c. "	627,170	22,078
Pumps, N.E.S	$	25 %	....	179,141
Safes, doors for safes and vaults	"	30 "	....	12,014
Screws, iron and steel, commonly called "woodscrews," N.E.S	Lbs.	35 "	133,855	17,318
Scales, balances, weighing beams and strength testing machines	$	30 "	....	95,658
Skates of all kinds and parts thereof	Pairs	35 "	31,500	14,491
Stoves of all kinds and parts thereof, N.E.S.	$	25 "	....	128,747
Stove plates, and sad or smoothing, hatters' and tailors' irons, plated wholly or in part or not	"	25 "	....	10,050
Carried forward		....	....	8,745,430

IRON.

Imports.

TABLE 10b—*Continued.*

IRON.

IMPORTS OF IRON AND STEEL GOODS.

Fiscal Year, 1901.		Duty.	Quantity.	Value.
Brought forward				8,745,430
Tubing:				
Boiler tubes of wrought iron or steel, including flues and corrugated tubes for marine boilers	Lbs.	5 %	4,991,898	231,209
Tubes of rolled steel, seamless, not joined or welded, not more than 1½ inches in diameter	"	10 "	86,225	3,559
Tubes, seamless steel, for bicycles	"	10 "	282,473	32,843
Tubing, wrought iron or steel, plain or galvanized, threaded and coupled or not, over two inches in diameter, N.E.S	"	15 "	5,551,525	227,701
Tubing, wrought iron or steel, plain or galvanized, threaded and coupled or not, 2 inches or less in diameter, N.E.S	"	35 "	2,252,598	85,310
Other iron or steel tubes or pipes, N.O.P.	"	30 "	588,587	35,496
Ware, galvanized sheet iron or of galvanized sheet steel, manufactures of, N.O.P.	$	25 "	....	44,535
Ware, agate, granite or enamelled iron or steel hollow ware	"	35 "	....	22,740
Ware, enamelled iron or steel ware, N.E.S., iron or steel hollow ware, plain black, tinned or coated, and nickel and aluminium kitchen or household hollow ware, N.E.S	"	30 "	....	60,005
Wire cloth or wove wire and netting of iron or steel	Lbs.	30 "	463,234	32,032
Wire screens, doors and windows	$	30 "	....	11,426
Wire fencing, woven, buckthorn strip and wire fencing of iron or steel, N.E.S.	Lbs.	15 "	1,892,541	67,548
Wire, single or several, covered with cotton, linen, silk, rubber or other material, &c., N.E.S.	"	30 "	2,753,378	354,859
Wire of all kinds, N.O.P.	"	20 "	2,785,510	99,856
Wire rope, stranded or twisted wire, clothes lines, picture or other twisted wire and wire cables, N.E.S.	"	25 "	1,541,186	120,935
Iron or steel nuts, washers, rivets and bolts with or without threads and nut bolt and hinge blanks, and T. and strap hinges of all kinds, N.E.S	"	¾ c.p. lb. and 25 %	1,932,240	79,488
Pen-knives, jack-knives and pocket knives of all kinds	$	30 %	....	88,835
Table cutlery, all kinds, N.O.P	"	30 "	....	196,418
All other cutlery, N.E.S	"	30 "	....	198,122
Guns, rifles, including air guns and air rifles, (not being toys) muskets, cannons, pistols, revolvers, or other firearms	"	30 "	....	180,072
Bayonets, swords, fencing foils and masks	"	30 "	....	1,772
Needles of any material or kind, N.O.P.	"	30 "	....	53,232
Carried forward				10,973,358

TABLE 10*b*—*Continued.*

IRON.

IMPORTS OF IRON AND STEEL GOODS.

Fiscal Year, 1901.		Duty.	Quantity.	Value.
				$
Brought forward				10,973,358
Tools and implements :				
Adzes, cleavers, hatchets, wedges, sledges, hammers, crow bars, cant dogs and track tools, picks, mattocks and eyes or poles for the same	$	30 %		21,013
Axes	Doz.	25 "	5,120	29,590
Saws	$	30 "		90,561
Files and rasps, N.E.S.	"	30 "		83,568
Tools, hand or machine, of all kinds, N.O.P	"	30 "		526,020
Knife blades, or blanks, and forks of iron or steel, in the rough not handled, filed, ground or otherwise manufactured	"	10 "		882
Manufactured articles or wares not specially enumerated or provided for, composed wholly or in part of iron or steel, and whether partly or wholly manufactured.	"	30 "		1,346,747
Anchors	Cwt.	Free	3,838	19,567
Iron or steel, rolled round wire rods, in the coil not over ⅜-inch in diameter, imported by wire manufacturers for use in making wire in the coil in their factories	"	"	410,094	645,136
Iron or steel masts, or parts of	"	"	24	52
Rolled iron tubes not welded, or joined, under 1½ inch in diameter, angle iron 9 and 10 gauge, not over 1½ inch wide, iron tubing lacquered or brass covered, not over 1½ inch diameter, all of which are to be cut to lengths for the manufacture of bedsteads, and to be used for no other purpose, and brass trimmings for bedsteads imported for the manufacture of iron or brass bedsteads	"	"	19,762	57,659
Steel bowls for cream separators and cream separators	$	"		260,969
Steel rails weighing not less than 45 lbs. per lineal yard for use only in the tracks of railways which are employed in the common carrying of goods and passengers, and are operated by steam motive power only	Cwt.	"	2,514,785	3,329,919
Steel strip and flat steel wire imported by manufacturers of buckthorn and plain strip fencing, for use in their own factories in the manufacture thereof	"	"	107	299
Steel wire, Bessemer soft drawn spring of Nos. 10, 12 and 13 gauge respectively, and homo steel spring wire of Nos. 11 and 12 gauge, respectively, imported by manufacturers of wire mattresses, to be used in their own factories in the manufacture of such articles	"	"	3,708	13,021
Carried forward				17,398,361

IRON.

Imports.

TABLE 10b—*Concluded.*

IRON.

IMPORTS OF IRON AND STEEL GOODS.

Fiscal Year, 1901.		Duty.	Quantity.	Value.
				$
Brought forward				17,398,361
Flat steel wire of No. 16 gauge or thinner imported by the manufacturers of crinoline, corset wire and dress stays, for use in the manufacture of such articles in their own factories	Cwt.	Free.	2,006	13,822
Flat spring steel, steel billets and steel axle bars, imported by manufacturers of carriage springs and carriage axles for use exclusively in the manufacture of springs and axles for carriages or vehicles other than railway or tramway, in their own factories	"	"	35,106	72,190
Spiral spring steel for spiral springs for railways, imported by the manufacturers of railway springs for use exclusively in the manufacture of railway spiral springs in their own factories	"	"	16,826	30,251
Wire, crucible cast steel	Lbs.	"	1,025,416	82,063
Galvanized iron or steel wire Nos. 9, 12 and 13 gauge	Cwt.	"	124,858	326,633
Total				17,923,320

TABLE 11.

IRON.

IMPORTS OF PIG IRON, IRON AND STEEL GOODS, &C., FISCAL YEAR, 1900-1901.

Recapitulation of Tables, 7, 8, 9, 10a and 10b.

——	Tons.	Value.
Pig iron and iron kentledge	35,293	$ 548,033
Pig iron, charcoal	490	7,121
Scrap iron, cast	4,499	51,032
Scrap steel, wrought	24,773	242,189
Ferro-manganese, &c	1,512	38,954
Iron in slabs, blooms, puddled bars, &c	11,746	206,975
Iron and steel goods partially manufactured		5,633,168
Iron and steel goods highly manufactured*		17,923,320
Total		$24,650,792

*Machinery, &c., classed under iron and steel goods in Customs report.

LEAD.

Lead.

Production.

With the exception of a very small output from the eastern provinces, the lead production in Canada is still derived entirely from the province of British Columbia.

The total production in 1901 amounted to nearly 26,000 tons and although this is a decrease as compared with the year 1900 of over 17 per cent, it is still 33 per cent greater than the highest output of any year previous to 1900.

TABLE 1.

LEAD.

ANNUAL PRODUCTION.

Calendar Year.	Pounds.	Price per Pound.	Value.
		cts.	
1887	204,800	4·50	$ 9,216
1888	674,500	4·42	29,812
1889	165,100	3·93	6,488
1890	105,000	4·48	4,704
1891	88,665	4·35	3,857
1892	808,420	4·09	33,064
1893	2,135,023	3·73	79,636
1894	5,703,222	3.29	187,636
1895	16,461,794	3·23	531,716
1896	24,199,977	2·98	721,159
1897	39,018,219	3.58	1,396,853
1898	31,915,319	3·78	1,206,399
1899	21,862,436	4·47	977,250
1900	63,169,821	4·37	2,760,521
1901	51,900,958	4·334	2,249,387

In order to encourage the establishment of plants for the refining of lead ores within Canada, the Dominion at its last session provided for the payment of a bounty on lead refined in Canada from materials produced by Canadian smelters from Canadian lead ores (1 Edward VII, Chap. 8). In effect the act provided for the payment of the bounty for five years, beginning the first day of July 1902, the rates to be five dollars per ton for the first year, and decreasing one dollar per ton each year thereafter. The total sum payable for such bounties is not to exceed one hundred thousand dollars in any year.

Lead.

Production.

The value of the exports of lead in ore, &c., is shown in Table 2, while the imports are given in Tables 3 and 4 and of litharge in Table 5. Imports of dry white and red lead are shown in Table 6. In the latter table since 1890 the imports of zinc-white have been included with the lead oxides.

The total value of the imports in 1901 including lead manufactured and unmanufactured, lead oxides and zinc-white amounted to $890,510.

Exports.

Table 2.

Lead.

Exports.

Calendar Year.	Value.
1873	$1,993
1874	127
1875	7,510
1876	66
1877	720
1878	....
1879	230
1880	....
1881	....
1882	32
1883	5
1884	36
1885	....
1886	....
1887	724
1888	18
1889	....
1890	....
1891	5,000
1892	2,509
1893	3,099
1894	144,509
1895	435,071
1896	462,095
1897	925,144
1898	885,485
1899	466,950
1900	1,017,690
1901	1,804,687

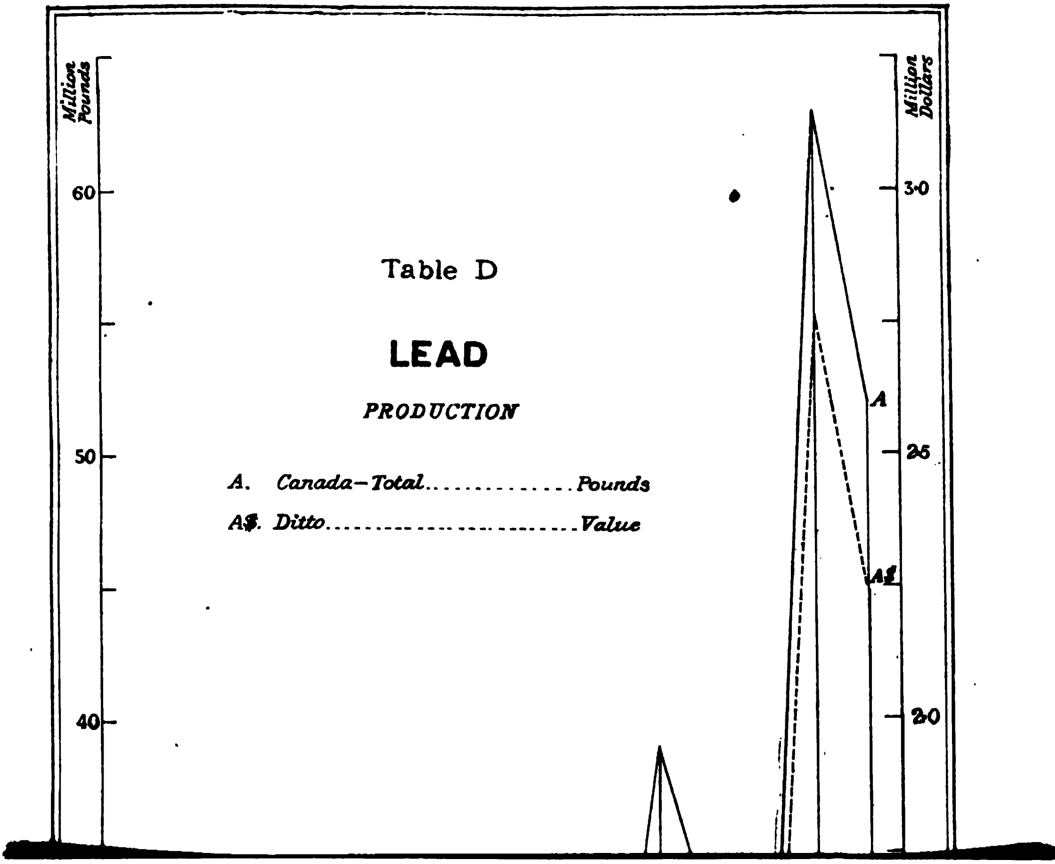


Table D

LEAD

PRODUCTION

LEAD.
Imports.

TABLE 3.

LEAD.

IMPORTS OF LEAD.

Fiscal Year.	OLD, SCRAP AND PIG.		BARS, BLOCKS, SHEETS.		TOTAL.	
	Cwt.	Value.	Cwt.	Value.	Cwt.	Value.
1880	....	....	....	....	30,298	$124,117
1881	16,236	$ 56,919	18,222	$70,744	34,458	127,663
1882	36,655	120,870	10,540	35,728	47,195	156,598
1883	48,780	148,759	8,591	28,785	57,371	177,544
1884	39,409	103,413	9,704	28,458	49,113	131,871
1885	36,106	87,038	9,362	24,396	45,468	111,434
1886	39,945	110,947	9,793	28,948	49,738	139,895
1887	61,160	173,477	14,153	41,746	75,313	215,223
1888	68,678	196,845	14,957	45,900	83,635	242,745
1889	74,223	213,132	14,173	43,482	88,396	256,614
1890	101,197	283,096	19,083	59,484	120,280	342,580
1891	86,382	243,033	15,646	48,220	102,028	291,253
1892	97,375	254,384	11,299	32,368	108,674	286,752
1893	94,485	215,521	12,403	32,286	106,888	247,807
1894	70,223	149,440	8,486	20,451	78,709	169,891
1895	67,261	139,290	6,739	16,315	74,000	155,605
1896	72,433	173,162	8,575	23,169	81,008	196,331
1897	65,279	158,381	10,516	29,175	75,795	187,556
	OLD, SCRAP, PIG AND BLOCK.*		BARS AND SHEETS.†		TOTAL.	
1898	88,420	$260,779	22,214	$39,041	110,634	$299,820
1899	114,659	283,432	44,796	39,833	159,455	323,265
1900	62,361	207,819	15,493	53,506	77,854	251,325
1901	(a)85,321	97,011	16,295	78,316	101,616	175,327

* Duty 15 p. c.

† Duty 25 p. c.

(a) Includes Canadian lead ore sent to the United States for refining, imported at price of refining only.

Lead.

Imports.

Table 4.

Lead.

Imports of Lead Manufactures.

Fiscal Year.	Value.	Fiscal Year.	Value.
1880	$15,400	1891	23,893
1881	22,629	1892	22,636
1882	17,282	1893	33,783
1883	25,556	1894	29,361
1884	31,361	1895	38,015
1885	36,340	1896	50,722
1886	33,078	1897	60,735
1887	19,140	1898	63,179
1888	18,816	1899	91,497
1889	16,315	1900	104,736
1890	25,600		

		Duty.	
1901	Lead Tea	Free.	$41,776
	" Pipe	35 p. c.	11,789
	" Shot and bullets	35 "	2,535
	" Manufactures, N.E.S	30 "	51,160
	Total		$107,260

Table 5.

Lead.

Imports of Litharge.

Fiscal Year.	Cwt.	Value.
1880	3,041	$14,334
1881	6,126	22,129
1882	4,900	16,651
1883	1,532	6,173
1884	5,235	18,132
1885	4,990	16,156
1886	4,928	16,003
1887	6,397	21,865
1888	7,010	23,808
1889	8,089	31,082
1890	9,453	31,401
1891	7,979	27,613
1892	10,384	34,343
1893	7,685	24,401
1894	38,547	28,685
1895	11,955	32,953
1896	10,710	32,817
1897	12,028	34,538
1898	11,446	32,904
1899	9,530	32,518
1900	9,139	29,176
1901 Duty free	11,132	51.944

TABLE 6.

LEAD.

IMPORTS OF DRY WHITE AND RED LEAD AND ORANGE MINERAL.

LEAD.

Imports.

Fiscal Year.	Pounds.	Value.
		$
1885........................	5,404,753	198,913
1886........................	6,703,077	213,258
1887........................	6,998,820	233,725
1888........................	6,361,334	216,654
1889........................	7,066,465	267,236

IMPORTS OF DRY WHITE AND RED LEAD, ORANGE MINERAL AND ZINC WHITE

Fiscal Year.	Pounds.	Value.
		$
1890........................	10,859,672	381,959
1891........................	8,560,615	337,407
1892........................	10,288,766	351,686
1893........................	10,865,183	364,680
1894........................	10,958,170	353,053
1895........................	8,780,052	282,353
1896........................	11,711,496	367,569
1897........................	10,310,468	347,539
1898........................	12,682,808	448,659
1899........................	14,507,945	514,842
1900........................	14,679,920	634,492
1901............Duty, 5 p.c.	10,241,601	461,868

Lead.

Production.

British Columbia.

British Columbia—

The production of lead in British Columbia since 1887 is shown in Table 7 below.

Table 7.

Lead.

British Columbia : Production.

Calendar Year.	Pounds.	Price per Pound.	Value.
		cts.	
1887	204,800	4·50	$ 9,216
1888	674,500	4·42	29,813
1889	165,100	3·93	6,488
1890	Nil.	....	....
1891	"	....	....
1892	808,420	4·09	33,064
1893	2,131,092	3·73	79,490
1894	5,703,222	3·29	187,636
1895	16,461,794	3·23	531,716
1896	24,199,977	2·98	721,159
1897	38,841,135	3·58	1,390,513
1898	31,693,559	3·78	1,198,017
1899	21,862,436	4·47	977,250
1900	63,158,621	4·37	2,760,031
1901	51,582,906	4·334	2,235,603

The various mining districts have contributed to the output for 1900 and 1901 as follows:—

——	1900.	1901.
	Pounds.	Pounds.
East Kootenay—		
Fort Steele	38,494,077	29,129,128
Other districts	81,354	775,016
West Kootenay—		
Ainsworth	3,366,962	3,788,412
Nelson	1,485,899	2,470,350
Slocan	19,365,743	15,025,759
Trail Creek	1,045	....
Other districts	363,439	391,844
Yale	102	2,397
	63,158,621	51,582,906

Fort Steele again contributes the largest proportion of the output with 56 per cent of the whole, the Slocan occupying second place with 29 per cent.

MANGANESE.

MANGANESE.

Production.

There is nothing of special interest to report regarding manganese production in 1901.

The exports according to customs returns were 440 tons, valued at $4,820, and in the absence of complete returns of production this figure has been taken as the output for the year.

Statistics of production, exports and imports are given in the following tables:—

TABLE 1.

MANGANESE.

ANNUAL PRODUCTION.

Calendar Year.	Tons.	Value.	Value per ton.
1886	1,789	$41,499	$23 20
1887	1,245	43,658	35 07
1888	1,801	47,944	26 62
1889	1,455	32,737	22 50
1890	1,328	32,550	24 51
1891	255	6,694	26 25
1892	115	10,250	89 13
1893	213	14,578	68 44
1894	74	4,180	56 49
1895	125	8,464	67 71
1896*	123½	3,975	32 19
1897*	15¼	1,166	76 46
1898	50	1,600	32 00
1899	1,581	20,004	12 65
1900	30	1,800	60 00
1901*	440	4,820	10 95

* Exports.

Manganese.

Exports.

TABLE 2.

MANGANESE.

EXPORTS OF MANGANESE ORE.

Calendar Year.	Nova Scotia.		New Brunswick.		Total.	
	Tons.	Value.	Tons.	Value.	Tons.	Value.
1873	....	....	1,031	$20,192	1,031	$20,192
1874	6	$ 12	776	16,961	782	16,973
1875	....	200	194	5,314	203	5,514
1876	21	723	391	7,316	412	8,039
1877	106	3,699	785	12,210	891	15,909
1878	106	4,889	520	5,971	626	10,860
1879	154	7,420	1,732	20,016	1,886	27,436
1880	79	3,090	2,100	31,707	2,179	34,797
1881	200	18,022	1,504	22,532	1,704	40,554
1882	123	11,520	771	14,227	894	25,747
1883	313	8,635	1,013	16,708	1,326	25,343
1884	134	1,054	469	9,035	603	20,089
1885	77	5,054	1,607	29,595	1,684	34,649
1886	(*a*) 441	854	1,377	27,484	(*a*)1,818	58,338
1887	578	14,240	837	20,562	1,415	34,802
1888	87	5,759	1,094	16,073	1,181	21,832
1889	59	3,024	1,377	26,326	1,436	29,350
1890	177	2,583	1,729	34,248	1,906	36,831
1891	22	563	233	6,131	255	6,694
1892	84	6,180	59	2,025	143	8,205
1893	123	12,409	10	112	133	12,521
1894	11	720	45	2,400	56	3,120
1895	108	6,348	$\frac{1}{16}$	3	$108\frac{1}{16}$	6,351
1896	$123\frac{1}{2}$	3,975	....	....	$123\frac{1}{2}$	3,975
1897	$15\frac{1}{4}$	1,166	....	....	$15\frac{1}{4}$	1,166
1898	11	325	....	....	11	325
1899	67	2,328	3	82	70	2,410
1900	....	....	....	....	34	1,720
1901	....	....	....	....	440	4,820

(*a*) 250 tons from Cornwallis should more correctly be classed under the heading of mineral pigments.

TABLE 3.

MANGANESE.

Imports.

IMPORTS: OXIDE OF MANGANESE.

Fiscal Year.	Tons.	Value.	Fiscal Year.	Tons.	Value.
1884	3,989	$ 258	1893	94,116	$3,696
1885	36,778	1,794	1894	101,863	4,522
1886	44,967	1,753	1895	64,151	2,781
1887	59,655	2,933	1896	108,590	4,075
1888	65,014	3,022	1897	70,663	2,741
1889	52,241	2,182	1898	130,456	5,047
1890	67,452	3,192	1899	141,356	5,539
1891	92,087	3,743	1900	126,725	4,155
1892	76,097	3,530	1901....Duty free	272,134	8,176

MICA.

Mica.

Production.

The production of mica has been calculated according to the practice followed during the past few years, viz., of adding to the known exports an estimate of the value of the home consumption. On this basis the production for 1901 was valued at $160,000.

Statistics of production and exports are given in Tables 1 and 2.

TABLE 1.

MICA.

ANNUAL PRODUCTION.

Calendar Year.	Value.	Calendar Year.	Value.
1886	$ 29,008	1894	$45,581
1887	29,816	1895	65,000
1888	30,207	1896	60,000
1889	28,718	1897	76,000
1890	68,074	1898	118,375
1891	71,510	1899	163,000
1892	104,745	1900	166,000
1893	75,719	1901	160,000

Exports.

TABLE 2.

MICA.

EXPORTS.

Calendar Year.	Value.	Calendar Year.	Value.
1887	$ 3,480	1895	48,525
1888	23,563	1896	47,756
1889	30,597	1897	69,101
1890	22,468	1898	110,507
1891	37,590	1899	153,002
1892	86,562	1900	146,750
1893	70,081	1901	152,553
1894	38,971		

MINERAL PIGMENTS.

MINERAL PIGMENTS.

Production.

Under this heading is included the production of ochres and baryta.

Ochres.

Ochres.—The production of ochres in 1901 amounted to 2,233 tons, valued at $16,735. The output is mined from deposits near Three Rivers, Champlain county, Quebec, and is used chiefly in the manufacture of paints. The firms engaged in the production were, The Canada Paint Company, Montreal, the Champlain Oxide Company, Three Rivers, and Thomas H. Argall, Three Rivers.

Statistics of production, imports and exports are given in Tables 1, 2 and 3.

TABLE 1.

MINERAL PIGMENTS.

ANNUAL PRODUCTION OF OCHRES.

Calendar Year.	Tons.	Value.
1886	350	$ 2,350
1887	485	3,733
1888	397	7,900
1889	794	15,280
1890	275	5,125
1891	900	17,750
1892	390	5,800
1893	1,070	17,710
1894	611	8,690
1895	1,339	14,600
1896	2,362	16,045
1897	3,905	23,560
1898	2,226	17,450
1899	3,919	20,000
1900	1,966	15,398
1901	2,233	16,735

MINERAL PIGMENTS.

Imports of ochres.

TABLE 2.

MINERAL PIGMENTS.

IMPORTS OF OCHRES.

Fiscal Year.	Duty.	Pounds.	Value.
1880		571,454	$ 6,544
1881		677,115	8,972
1882		731,526	8,202
1883		898,376	10,375
1884		533,416	6,393
1885		1,119,177	12,782
1886		1,100,243	12,267
1887		1,460,128	17,067
1888		1,725,460	17,664
1889		1,342,783	12,994
1890		1,394,811	14,066
1891		1,528,696	20,550
1892		1,708,645	22,908
1893		1,968,645	23,134
1894		1,358,326	18,951
1895		793,258	12,048
1896		1,159,494	16,954
1897		1,504,044	18,504
1898		2,126,592	26,307
1899		2,444,698	31,092
1900		2,474,537	32,017
1901 Ochres and ochrey earths and raw siennas	20 p. c.	805,509	$ 7,849
1901 Oxides, dry fillers, fire-proofs umbers and burnt siennas N.E.S.	25 "	1,286,558	19,418
Total, 1901		2,092,067	$27,267

Exports.

TABLE 3.

MINERAL PIGMENTS.

EXPORTS OF MINERAL PIGMENTS, IRON OXIDES &c.

Calendar Year.	Tons.	Value.
1897	512	$7,706
1898	283	4,227
1899	308	5,408
1900	651	7,154
1901	401	8,233

Baryta.

Baryta.—The baryta produced during the past five or six years has been obtained near Lake Ainslie, Inverness county, and from Brookfield, Colchester county, Nova Scotia, while a small quantity has also been mined near Cantley, Hull township, Quebec.

MINERAL PIGMENTS.

Baryta.

Production.

TABLE 4.

MINERAL PIGMENTS.

ANNUAL PRODUCTION OF BARYTA.

Calendar Year.	Tons.	Value.
1885	300	$ 1,500
1886	3,864	19,270
1887	400	2,400
1888	1,100	3,850
1889	....	....
1890	1,842	7,543
1891	....	....
1892	315	1,260
1893	....	....
1894	1,081	2,830
1895	....	....
1896	145	715
1897	571	3,060
1898	1,125	5,533
1899	720	4,402
1900	1,337	7,605
1901	653	3,842

Imports.

TABLE 5.

MINERAL PIGMENTS.

IMPORTS OF BARYTA.

Fiscal Year.	Cwt.	Value.
1880	2,230	$ 1,525
1881	3,740	1,011
1882	497	303
1883	....	185
1884	....	229
1885	7	14
1886	....	62
1887	379	676
1888	236	214
1889	1,332	987
1890	1,322	978

MINERAL PIGMENTS.

Miscellaneous imports.

TABLE 6.

MINERAL PIGMENTS.

MISCELLANEOUS IMPORTS, FISCAL YEAR, 1901.

—	Duty.	Quantity.	Value.
			$
Paint, ground or mixed in, or with either japan, varnish, lacquers, liquid dryers, collodion, oil finish or oil varnish...... Lbs.	25 p. c.	56,463	3,924
Paints and colours, and rough stuff and fillers, anti-corrosive and anti-fouling paints commonly used for ship hulls, N.E.S. .... "	25 "	262,672	15,198
Paris green, dry.. .... "	10 "	335,173	32,510
Paints and colours ground in spirits, and all spirit varnishes and lacquers .... Galls.	$1.12½ par gallon..	456	1,520
Putty..... .... Lbs.	20 p. c.	238,996	3,544
Total	....	....	56,696

MINERAL WATER.

MINERAL WATER.

Production.

Mineral springs are known to occur at many places throughout Canada, and at a number of them the water is being utilized, either put up in bottles for sale throughout the country, or used for drinking or bathing purposes at the places where it is found. At several points, hotels have been erected, at which the guests have the privilege of using the mineral water at the place. In view of this, it is difficult to obtain statistics giving any intelligent idea of the extent or value of the industry.

Statistics of production and imports are given in Tables 1 and 2.

TABLE 1.

MINERAL WATERS.

ANNUAL PRODUCTION.

Calendar Year.	Gallons.	Value.	Calendar Year.	Gallons.	Value.
1888.............	124,850	$ 11,456	1895.............	739,382	$126,048
1889.............	424,600	37,360	1896.............	706,372	111,736
1890.	561,165	66,031	1897.......... .. .	749,691	141,477
1891.............	427,485	54,268	1898.............	555,000	100,000
1892.............	640,380	75,348	1899...	....	100,000
1893.............	725,096	108,347	1900.............	....	75,000
1894.............	767,460	110,040	1901..	....	100,000

MINERAL WATER.

Imports.

TABLE 2.

MINERAL WATERS.

IMPORTS.

Fiscal Year.	Value.	Fiscal Year.	Value.
1880	$15,721	1891	$41,797
1881	17,913	1892	55,763
1882	27,909	1893	57,953
1883	28,130	1894	49,546
1884	27,879	1895	48,613
1885	32,674	1896	55,864
1886	22,142	1897	47,006
1887	33,314	1898	52,989
1888	38,046	1899	54,891
1889	30,343	1900	66,331
1890	40,802		
1901 { Mineral waters, natural, not in bottle		Duty free	$ 749
1901 { Mineral and aerated waters		" 20 p.c.	70,772
Total			$71,521

NATURAL GAS.

Production.

NATURAL GAS.

The total value of the natural gas sold in Canada in 1901 was $339,476. This output is practically all derived from the wells in southern Ontario, although at Medicine Hat, N.W.T., a small quantity is used for the burning of lime.

TABLE 1.

NATURAL GAS.

ANNUAL PRODUCTION.

Calendar Year.	Value.
1892	$ 150,000
1893	376,233
1894	313,754
1895	423,032
1896	276,301
1897	325,873
1898	322,123
1899	387,271
1900	417,094
1901	339,476

NICKEL.

Nickel.

Production.

The production of nickel in Canada in 1901 from the nickel-copper ores of the Sudbury district, Ontario, amounted to 9,189,047 pounds, or 4,594 tons as compared with 7,080,227 pounds or 3,540 tons in 1900, an increase of 1,054 tons or nearly 30 per cent. The price of refined nickel at New York was steady throughout the year, ranging from 50c. to 60c. per pound, according to size and terms of order.

The companies operating in the Sudbury district are

The Canadian Copper Company,

The Mond Nickel Company,

The Lake Superior Power Company,

The Nickel Copper Company of Ontario.

Of these, the first two operate smelting plants, producing nickel-copper matte. The operations of the Lake Superior Power Company have so far been limited to development work on their properties.

TABLE 1.

NICKEL.

ANNUAL PRODUCTION.

Calendar Year.	Pounds of Nickel in Matte.	Final Average Market Price per lb. at New York.	Value.
1889	*830,477	60c.	$ 498,286
1890	1,435,742	65c.	933,232
1891	4,626,627	60c.	2,775,976
1892	2,413,717	58c.	1,399,956
1893	3,982,982	52c.	2,071,151
1894	4,907,430	38⅛c.	1,870,958
1895	3,888,525	35c.	1,360,984
1896	3,397,113	35c.	1,188,990
1897	3,997,647	35c.	1,399,176
1898	5,517,690	33c.	1,820,838
1899	5,744,000	36c.	2,067,840
1900	7,080,227	47c.	3,327,707
1901	9,189,047	50c.	4,594,523

* Calculated from shipments made by rail.

NICKEL.

Exports.

TABLE 2.

NICKEL.

EXPORTS.*

Calendar Year.	Value.
1890	$ 89,568
1891	667,280
1892	293,149
1893	629,692
1894	559,356
1895	521,783
1896	658,213
1897	723,130
1898	1,019,363
1899	939,915
1900	1,031,030
1901	751,080

*Practically all the nickel-bearing ore and matte produced in Canada is exported, the apparent discrepancy between Tables Nos. 1 and 2 being due to the different basis of valuation adopted in the two instances. Table 1 represents the total final values of the nickel produced in Canada, for the years represented. In Table 2 the worth of the product shipped is entered at its spot value to the operators, and depends upon the particular stage to which they happened to carry the process of extraction at the time, *e.g.*, whether the shipments made are raw ore, low grade matte or high grade matte, &c.

TABLE 3.

NICKEL.

IMPORTS.

Imports.

Calendar Year.		Value.
1890		$ 3,154
1891		3,889
1892		3,208
1893		2,905
1894		3,528
1895		4,267
1896		4,787
1897		4,737
1898		5,882
1899		9,449
1900		6,988
	Duty.	
1901 Nickel anodes	10 p. c.	11,965
1901 Nickel*	Free.	64
		$ 12,029

*Classified under the general heading of minerals in the Trade and Navigation Report.

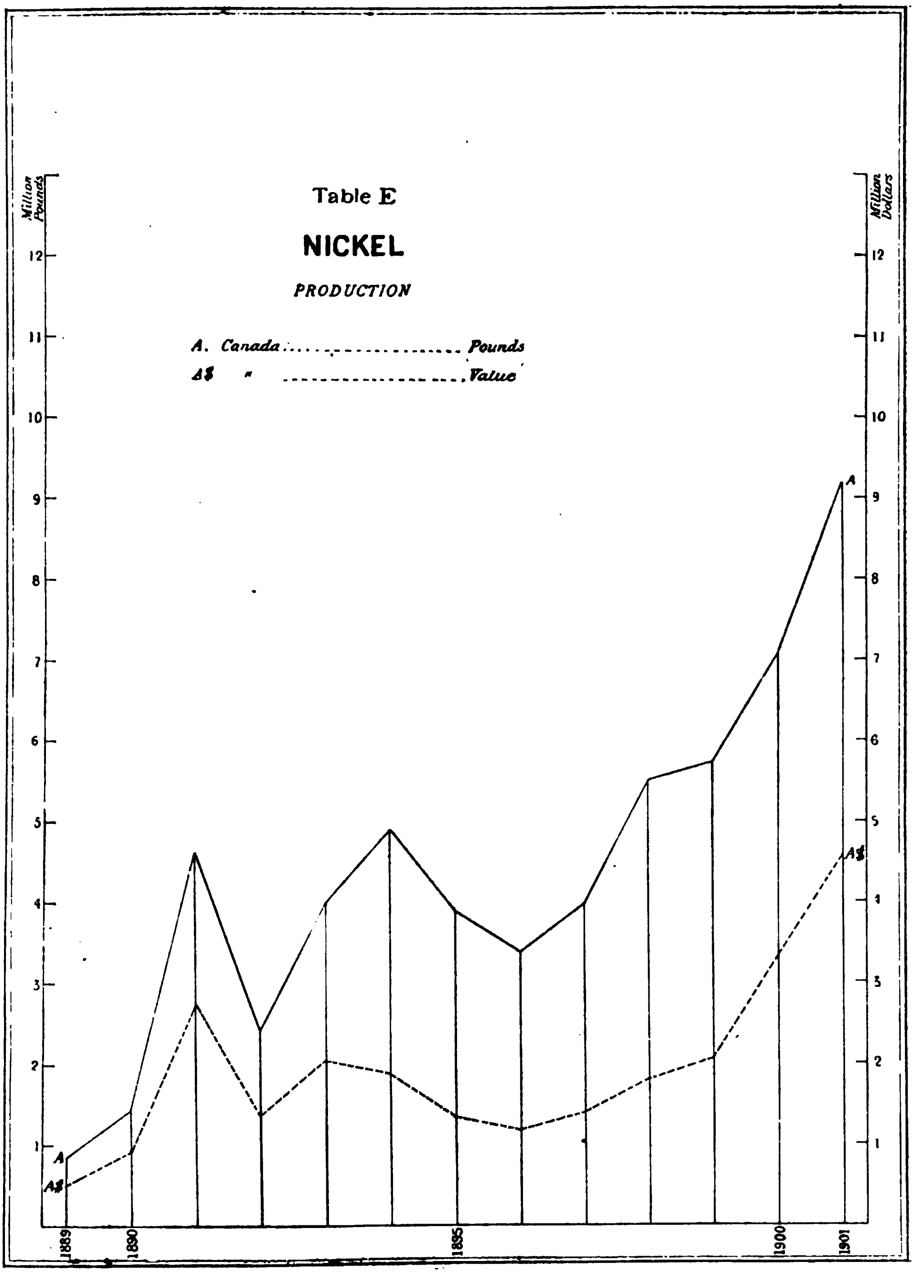


Table E
NICKEL
PRODUCTION
A. Canada .... Pounds
A$ " .... Value
Million Pounds
Million Dollars
12
11
10
9
8
7
6
5
4
3
2
1
A
A$
1889
1890
1895
1900
1901

14—s—7

PETROLEUM.

PETROLEUM.

During the past two years a considerable quantity of crude petroleum has been sold directly for gas-making, fuel, lubricating and other purposes. The quantity sold in this way in 1901 was, according to returns received from shippers 113,715 barrels, while the sales to refineries reached a total of 508,677 barrels. Thus the total sales of crude oil for the year amounted to 622,392 barrels, valued at $1,008, 275 or an average of $1.62 per barrel. These figures do not of course include stocks on hand on December 31, 1901, but on the other hand they do or should include stocks which were held at December 31, 1900, and sold during the year 1901.

Messrs. Chas. Jenkins, president of the Petroleum Crude Oil Tanking Company, and Mr. O. Simmons, M.P., of Petrolia, very kindly placed us in possession of important information concerning the increasing sale and shipment of oil for gas and fuel purposes, which has enabled us to arrive at a close approximation to the quantity used in this way as given above.

In former years, when the crude oil was practically all sent to Canadian refineries, an estimate of the production was arrived at by taking the quantity of refined oils inspected and deducing therefrom the quantity of crude oil used. A statement of the production from 1881 to 1900, calculated on this basis, will be found in Table 1.

In Table 2 statistics are shown of the value of the petroleum products of the refineries.

PETROLEUM.

Inspection of oils.

TABLE 1.

PETROLEUM.

CANADIAN OILS AND NAPHTHA INSPECTED AND CORRESPONDING QUANTITIES OF CRUDE OIL.

Calendar Year.	Refined Oils Inspected.	Crude Equivalent Calculated.	Ratio of Crude to Refined.	Equivalent in Barrels of 35 Gallons	Average Price per Barrel of Crude.	Value of Crude Oil.
	Galls.	Galls.				
1881	6,457,270	12,914,540	100:50	368,987	....	....
1882	6,135,782	13,635,071	100:45	389,573	....	....
1883	7,447,648	16,550,328	100:45	472,866	....	....
1884	7,903,995	19,984,987	100:40	571,000	....	....
1885	8,225,882	20,564,705	100:40	587,563	....	....
1886	7,768,006	20,442,121	100:38	584,061	$0 90	$525,655
1887	9,492,588	24,980,494	100:38	713,728	0 78	556,708
1888	9,246,176	24,332,042	100:38	695,203	1 02¾	713,695
1889	9,472,476	24,664,144	100:38	704,690	0 92¾	653,600
1890	10,174,894	26,776,037	100:38	795,030	1 18	902,734
1891	10,065,463	26,435,430	100:38	755,298	1 33¾	1,010,211
1892	10,370,707	27,291,334	100:38	779,753	1 26¼	984,438
1893	10,618,804	27,944,221	100:38	798,406	1 09½	874,255
1894	11,027,082	29,018,637	100:38	829,104	1 00¾	835,322
1895	10,674,232	25,414,838	100:42	726,138	1 49⅔	1,086,738
1896	10,684,284	25,438,771	100:42	726,822	1 59	1,155,647
1897	10,434,878	24,844,995	100:42	709,857	1 42½	1,011,546
1898	11,148,348	26,543,685	100:42	758,391	1 40	1,061,747
1899	11,927,981	28,399,955	100:42	808,570	1 48⅔	1,202,020
1900	13,428,422	24,867,449	100:54	710,498	1 62	1,151,007

TABLE 2.

PETROLEUM.

Value of production.

VALUE OF PRODUCTION OF CANADIAN OIL REFINERIES.

Calendar Year.	Value.
1887	$1,288,109
1888	1,401,459
1889	1,414,184
1890	1,638,420
1891	1,534,509
1892	1,782,365
1893	1,675,784
1894	1,567,134
1895	1,806,237
1896	1,876,913
1897	1,672,429
1898	1,825,265
1899	1,490,870
1900	1,620,705
1901	1,251,373

PETROLEUM.

Amount of oil inspected.

TABLE 3.

PETROLEUM.

TOTAL AMOUNT OF OIL INSPECTED, CANADIAN AND IMPORTED.

Fiscal Year	Canadian.	Imported.	Total.	Canadian.	Imported.
	Galls.	Galls.	Galls,	%	%
1881..........	6,406,783	476,784	6,883,567	93·1	6·9
1882..........	5,910,747	1,351,412	7,262,159	81·4	18·6
1883..........	6,970,550	1,190,828	8,161,378	85·4	14·6
1884.........	7,656,001	1,142,575	8,798,586	87·0	13·0
1885..........	7,661,617	1,278,115	8,939,732	85·7	14·3
1886..........	8,149,472	1,327,616	9,477,088	86·0	14·0
1887..........	8,243,962	1,665,604	9,909,566	83·2	16·8
1888..........	9,545,895	1,821,342	11,367,237	84·0	16·0
1889..........	9,462,834	1,767,812	11,230,646	84·3	15·7
1890..........	10,121,210	2,020,742	12,141,952	83·4	16·6
1891..........	10,270,107	2,022,002	12,292,109	83·6	16·4
1892..........	10,238,426	2,429,445	12,667,871	80·8	19·2
1893	10,683,806	2,641,690	13,325,496	80·2	19·8
1894..........	10,824,270	5,633,222	16,457,492	65·8	34·2
1895..........	10,936,992	5,650,994	16,587,986	65·9	34·1
1896..........	10,533,951	5,807,991	16,341,942	64·5	35·5
1897..........	10,506,526	6,248,743	16,755,269	62·7	37·3
1898..........	10,796,847	6,880,734	17,677,581	61·1	38·9
1899..........	11,005,804	7,232,348	18,238,152	60·3	39·7
1900..........	13,014,713	*8,216,207	21,230,920	61·3	38·7
1901..........	12,674,977	*9,232,165	21,907,142	57·9	42·1

* Item (*a*) Table 5.

Exports.

TABLE 4.

PETROLEUM.

EXPORTS OF CRUDE AND REFINED PETROLEUM.

Calendar Year.	Crude Oil.		Refined Oil.		Total.	
	Gallons.	Value.	Gallons.	Value.	Gallons.	Value.
1881	....	....	....	....	501	$ 99
1882	....	....	....	....	1,119	286
1883	....	....	....	....	13,283	710
1884	....	....	....	....	1,098,090	30,168
1885	....	....	....	....	337,967	10,562
1886	....	....	....	....	241,716	9,855
1887	....	....	....	....	473,559	13,831
1888	....	....	....	....	196,602	74,542
1889	....	....	....	....	235,855	10,777
1890	....	....	....	....	420,492	18,154
1891	446,770	$ 18,471	585	$104	447,355	18,575
1892	310,387	12,945	1,146	100	311,533	13,045
1893	107,719	3,696	2,196	394	109,915	4,090
1894	53,985	2,773	5,297	513	59,282	3,286
1895	22,831	1,044	10,237	2,023	33,068	3,067
1896	601	101	7,489	999	8,090	1,100
1897	....	....	342	49	342	49
1898	96	4	12,735	3,001	12,831	3,005
1899	....	....	3,425	859	3,425	859
1900	40	2	8,559	2,394	8,599	2,396
1901	14,168	691	375	66	14,543	757

PETROLEUM.

Imports.

TABLE 5.
PETROLEUM.
IMPORTS OF PETROLEUM AND PRODUCTS OF.

Fiscal Year.	Gallons.	Value.	Fiscal Year.	Gallons.	Value.
		$			$
1880	687,641	131,359	1891	5,071,386	498,330
1881	1,437,475	262,168	1892	5,649,145	475,732
1882	3,007,702	398,031	1893	6,002,141	446,389
1883	3,086,316	358,546	1894	6,597,108	439,988
1884	3,160,282	380,082	1895	7,577,674	525,372
1885	3,767,441	415,195	1896	8,005,891	735,913
1886	3,819,146	421,836	1897	8,415,302	697,169
1887	4,290,003	467,003	1898	9,074,311	724,519
1888	4,523,056	408,025	1899	10,394,208	763,803
1889	4,650,274	484,462	1900	9,633,647	864,833
1890	5,075,650	515,852			

		Duty.	Gallons.	$
1901	Oils: Mineral—			
	(*a*) Coal and kerosene, distilled, purified or refined, naphtha and petroleum, N.E.S.	5c. p. gall.	9,232,165	780,937
	(*b*) Products of petroleum	5c. "	328,181	34,462
	(*c*) Crude petroleum, fuel and gas oils (other than naphtha, benzine or gasoline) when imported by manufacturers (other than oil refiners) for use in their own factories, for fuel purposes or for the manufacture of gas	2½c. "	342,942	27,498
	(*d*) Illuminating oils composed wholly or in part of the products of petroleum, coal, shale or lignite, costing more than 30 cents per gallon	25 p. c.	11,691	4,213
	(*e*) Lubricating oils composed wholly or in part of petroleum, costing less than 25 cents per gallon	5c. p. gall.	1,147,843	135,530
	Total		11,062,822	982,640

TABLE 6.*
PETROLEUM.
IMPORTS OF CRUDE AND MANUFACTURED OILS, OTHER THAN ILLUMINATING.

Fiscal Year	Gallons.	Fiscal Year.	Gallons,
1881	960,691	1892	3,047,199
1882	1,656,290	1893	1,481,749
1883	1,895,488	1894	1,860,829
1884	2,017,707	1895	1,106,907
1885	2,489,326	1896	1,079,940
1886	2,491,530	1897	800,411
1887	2,624,399	1898	1,046,493
1888	2,701,714	1899	727,014
1889	2,882,462	1900	1,071,996
1890	3,054,908	1901	1,476,024
1891	3,049,384		

* This table is composed of items (*b*) and (*e*) of Table 5.

PETROLEUM.
Imports.

TABLE 7.

PETROLEUM.

IMPORTS OF PARAFFINE WAX.

Fiscal Year.	Pounds.	Value.
1883	43,716	$ 5,166
1884	39,010	6,079
1885	59,967	8,123
1886	62,035	7,953
1887	61,132	6,796
1888	53,862	4,930
1889	63,229	5,250
1890	239,229	15,844
1891	753,854	50,275
1892	733,873	48,776
1893	452,916	38,935
1894	208,099	15,704
1895	163,817	11,579
1896	150,287	10,042
1897	138,703	7,945
1898	103,570	5,987
1899	92,242	4,025
1900	47,400	3,529
1901...(Duty, 30 p. c.)	118,848	9,639

TABLE 8.

PETROLEUM.

IMPORTS OF PARAFFINE WAX CANDLES.

Fiscal Year.	Pounds.	Value.
1880	10,445	$2,269
1881	7,494	1,683
1882	5,818	1,428
1883	7,149	1,734
1884	8,755	2,229
1885	9,247	2,449
1886	12,242	2,587
1887	21,364	3,611
1888	22,054	2,829
1889	8,038	1,337
1890	7,233	1,186
1891	10,598	2,116
1892	9,259	1,952
1893	8,351	1,735
1894	10,818	1,685
1895	19,448	2,541
1896	25,787	4,072
1897	25,114	2,929
1898	60,802	4,427
1899	62,331	5,856
1900	27,663	3,671
1901..(Duty, 30 p.c.)	44,562	3,588

Petroleu
Prices.

TABLE 9.

PETROLEUM.

AVERAGE MONTHLY PRICES FOR CRUDE OIL AT PETROLIA DURING YEAR 1901.

MONTH.	PRICE.	MONTH.	PRICE.
January	$1 55 to $1·60	July	$1 41 to $1 61
February	1 55 to 1 60	August	1 61
March	1 60 to 1 61	September	1 61 to 1 66
April	1 51 to 1 59	October	1 66
May	1 41 to 1 51	November	1 66
June	1 41	December	1 61 to 1 66
		The Year	1 62

PHOSPHATE *(Apatite.)*

Phosphate.

Direct returns of the production of phosphate were not obtained. The production in Quebec according to Mr. Obalski was 1,033 tons, valued at$6, 280. This was obtained chiefly as a by-product in the mining of mica in the vicinity of Buckingham and Templeton.

TABLE 1.

PHOSPHATE.

ANNUAL PRODUCTION.

Calendar Year.	Tons.	Average Value per ton.	Value.
1886	20,495	$14 85	$304,338
1887	23,690	13 50	319,815
1888	22,485	10 77	242,285
1889	30,988	10 21	316,662
1890	31,753	11 37	361,045
1891	23,588	10 24	241,603
1892	11,932	13 20	157,424
1893	8,198	8 65	70,942
1894	6,861	6 00	41,166
1895	1,822	5 25	9,565
1896	570	6 00	3,420
1897	908	4 39	3,984
1898	733	5 00	3,665
1899	3,000	6 00	18,000
1900	1,415	5 02	7,105
1901	1,033	6 07	6,280

PHOSPHATE.
Exports.

TABLE 2.

PHOSPHATE.

EXPORTS.

Calendar Year.	Ontario.		Quebec.		Totals.	
	Tons.	*Value.	Tons.	*Value.	Tons.	*Value.
1878..........	824	$12,278	9,919	$195,831	10,743	$208,109
1879..........	1,842	20,565	6,604	101,470	8,446	122,035
1880..........	1,387	14,422	11,673	175,664	13,060	190,086
1881..........	2,471	36,117	9,497	182,339	11,968	218,456
1882..........	568	6,338	16,585	302,019	17,153	308,357
1883..........	50	500	19,666	427,168	19,716	427,668
1884..........	763	8,890	20,946	415,350	21,709	424,240
1885..........	434	5,962	28,535	490,331	28,969	496,293
1886..........	644	5,816	19,796	337,191	20,460	343,007
1887..........	705	8,277	22,447	424,940	23,152	433,217
1888..........	2,643	30,247	16,133	268,362	18,776	298,609
1889..........	3,547	38,833	26,440	355,935	29,987	394,768
1890..........	1,866	21,329	26,591	478,040	28,457	499,369
1891..........	1,551	16,646	15,720	368,015	17,271	384,661
1892..........	1,501	12,544	9,981	141,221	11,482	153,765
1893..........	1,990	11,550	5,748	56,402	7,738	67,952
1894..........	1,980	10,560	3,470	29,610	5,450	40,170
1895..........	....	....	250	2,500	250	2,500
1896..........	1	5	299	2,990	300	2,995
1897..........	70	450	165	400	235	850
1898..........	21	240	702	8,000	723	8,240
1899..........	215	1,850	93	1,725	308	3,575
1900..........	....	....	....	....	Nil	Nil
1901..........	....	....	....	....	6	120

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* These values do not compare with those in Table 1 above, the spot value being adopted for the production whilst the exports are valued upon quite a different basis.

PLATINUM.

PLATINUM.

Production.

As in the past the production of this metal is altogether derived from the placer working on the Similkameen river district of British Columbia. As will be seen on inspection of the figures in Table 1 below, the yield has been generally falling off for some years past. The amount is now insignificant.

PLATINUM.

Production.

TABLE 1.

PLATINUM.

ANNUAL PRODUCTION OF PLATINUM.

Calendar Year.	Value.
1887	$ 5,600
1888	6,000
1889	3,500
1890	4,500
1891	10,000
1892	3,500
1893	1,800
1894	950
1895	3,800
1896	750
1897	1,600
1898	1,500
1899	825
1900	Nil.
1901	457

As articles of platinum are not manufactured in Canada, there is no home market for the crude metal and the imports, as shown in Table 2, represent only the finished articles.

Imports.

TABLE 2.

PLATINUM.

IMPORTS OF PLATINUM.

Fiscal Year.	Value.
1883	$ 113
1884	576
1885	792
1886	1,154
1887	1,422
1888	13,475
1889	3,167
1890	5,215
1891	4,055
1892	1,952
1893	14,082
1894	7,151
1895	3,937
1896	6,185
1897	9,031
1898	9,781
1899	9,671
1900	57,910
1901*	20,263

*Platinum wire and platinum in bars, strips, sheets or plates: platinum retorts, pans, condensers, tubing and pipe, imported by manufacturers of sulphuric acid for use in their works. Duty free.

PLATINUM.

It is to be hoped that the increasing demand for this valuable metal may stimulate prospecting and lead to the discovery of other workable deposits. With this in view Mr. Theo. Denis, B. Sc., of the Staff of the Mines Section has prepared the following article on the subject, giving in condensed form, information inaccessible to the ordinary reader on account of its being scattered throughout a number of technical publications. Descriptive matter relating to the mode of occurrence and methods of working deposits in other countries has been included as suggestive of points likely to be of use to the prospector and miner in Canada.

OCCURRENCES OF PLATINUM IN CANADA.

Occurrences.

Although the first reference to the occurrence of platinum in Canada was made as early as 1852, by Dr. T. Sterry Hunt, yet, the production so far, as may be seen by the table given above, has been very small and moreover the figures show great irregularity from year to year. This is due to the fact that in Canada this metal is obtained as a by-product only, mainly in the working of some auriferous placers in British Columbia, and in many cases the black platiniferous sand which is held back in the riffles of the sluiceboxes, is overlooked and thrown away owing to the ignorance, on the part of the miners, of its value or of the mode of further treatment. Even as late as 1899, the Provincial Mineralogist for British Columbia in his report for the year says that 'It appears that many of the placer miners do not know its value and throw it away as so much black sand.' This may have been due to the fact that until a few years ago the demand for platinum was somewhat limited and the market price accordingly comparatively low; but at present, owing to its extended uses, the price has risen, so that it now rivals that of gold, the market price for ingot platinum during 1901, ranging from $18.00 to $22.00 per ounce.

Platinum was first noticed in Canada in 1852, as mentioned in the Geology of Canada of 1863. It was found on Rivière-du-Loup, province of Quebec, near its junction with the Chaudière, in the course of washing sand for gold. Associated with this native platinum were plates of a hard steel gray metal resembling iridosmine. There is also another record of platinum having been found under similar conditions in Rivière des Plantes, Beauce county, in the province of Quebec. The quantity was very small and these finds possess at present only a historical interest. If, however, placer mining should be more vigorously prosecuted in this region it is not impossible that platinum might become a valuable by-product of the operation.

PLATINUM.

Occurrences.

The recorded Canadian production of platinum comes from British Columbia, where the metal is obtained mainly in connection with the working of the auriferous deposits of the Similkameen and Tulameen rivers.

It is rather difficult to ascertain when platinum was first discovered in British Columbia. In his 'Mines and Minerals of Economic value of British Columbia,' (Geol. Surv. Rep. 76-77), the late Dr. G. M. Dawson mentioned finds of platinum on the Similkameen, Tranquille and Fraser rivers. But as some of those placers were first worked as far back as 1858 it is very probable that the black platiniferous sand must have come to the notice of gold miners a good many years before.

However, the first record of its having been saved is found in the report of the gold commissioner of the Similkameen division for 1886 in which he says: 'Mixed with the gold found in this district, and possessed of a greater specific gravity, is a whitish metal which at first was thrown away under the impression that it was worthless. For considerable time no definite idea could be procured as to its value. Mr. Jenson, of Granite City, who forwarded a sample to a cousin of his at Manchester, England, for analysis has kindly supplied me with the desired information. The metal is principally platinum, containing small quantities of iridium, osmium, and palladium. Its value depends on the percentage of platinum, which varies in quantity and may be considered as worth about $2.50 per ounce. The selling price at Granite City was 50 cents per ounce; so the purchasers will reap a handsome return for their investment.' The following year he estimates the production to have reached some 2,000 ounces, which commanded from $2.60 to $3.00 per ounce.

Platinum has been found in many places in British Columbia in association with gold, in alluvial deposits, an annotated list of localities being given below, but the region of the Similkameen and Tulameen rivers (north fork of Similkameen) is by far the most important.

The origin of the platinum found in the placers of the district, has not been definitely ascertained; Dr. Dawson in his report on the Mineral Wealth of British Columbia expresses himself as follows: The metal (platinum) occurs in notable quantity in the region of the upper Similkameen and Tulameen, in minute scales where the gold is "fine" but increasing in coarseness to small pellets and nuggets in places where "coarse" gold is found. Coarse grains and pellets of platinum have so far been found only on Granite, Cedar and Slate creeks, all entering the Tulameen on the south side. In certain claims in these creeks, the platinum has been found to equal half the weight of gold obtained .... Though above referred to as platinum, the metal so named is alloyed with several other metals of the same class, of which osmiridium is the most abundant. Specimens of the native platinum from Granite creek have been subjected to careful examination and analysis by Dr. Hoffmann, who states that the material "having the composition of the ore here in question would, at the present time, be worth, from $2.90 to $3.65 per ounce troy in the English market." Osmiridium is employed, on account of its great hardness, for tipping the nibs of gold pens. "For this purpose it is necessary that it should be in the form of natural grains, and these are very carefully selected, the requirements being that they should be solid, compact and the proper size and shape.' This was not however found to be the case with the grains present in the platinum from Granite creek.

PLATINUM.
Occurrences.

Platinum has very rarely been discovered in veins or otherwise in its original matrix. In Russia, whence the greatest quantities are obtained, it is almost always found as in the cases above cited in association with gold-bearing alluvions, although it has been noted in a few places with little or no accompanying gold. It appears to be derived from rocks consisting of serpentine and peridotite with talcose and chloritic schists and chromite. While there is a notable abundance of greenish chloritic and hornblendic schists and diabase rocks (resulting from the metamorphism of old volcanic rocks) in the Tulameen and upper Similkameen region of British Columbia, and chromite and magnetite are here found in the workings in association with the platinum and gold, no peridotite or serpentine is actually known to occur. The circumstances in connection with the occurrence of the 'coarse' platinum appear to point to the vicinity of an important mass of intrusive diorite as its point of origin. A great part of the associated magnetite is certainly derived from veins in this rock and it seems not improbable that the platinum, and possibly also a great part of the gold of this district, may occur in scattered grains in this intrusive mass. Very little vein-stuff occurs in the gravels with which the platinum and gold of this region are associated. (Geol. Surv. Rep. 87-88 part R.)

Later investigations however have led to a modification of the views expressed as above by Dr. Dawson in 1888.

The following statement by Mr. R. W. Brock was published in the Summary Report of the Geological Survey of Canada for 1901 p. 67: "It (platinum) has been found in the Similkameen district and is known to occur at many points in the western United States. When found in

PLATINUM. Occurrences.

place it has generally been confined to serpentine, and when found in sands it is usually in the neighborhood of serpentine. Consequently streams draining masses of serpentine in particular should be prospected for platinum. Serpentine, as above noted, occurs at a number of points in the district examined this summer, as on July creek, Hardy mountain and Central Camp. It also occurs on the range east of the Cascade."

A very interesting investigat'on on a sample of platinum from Granite creek was conducted by Dr. G. C. Hoffmann of the Geological Survey. The original sample weighed 18.266 grams, of which .372 consisted of rock matter, pyrite and gold. The sample was submitted to magnetic separation, and divided into two parts, which on analysis gave the following results :

	Non Magnetic.	Magnetic.
Weight	11·115 grams.	6·779 grams.
Platinum	69·19 °/₀	78·43 °/₀
Palladium	0·26	0·09
Rhodium.	3·10	1·70
Iridium	1·21	1.04
Osmium....	....	....
Copper.......................	3·09	3·89
Iron...................	·7·87	9·78
Osmiridium......	14·62	3·77
Gangue............	1·95	1·27
	100·29	99·97

This determination shows, therefore, a proportion of 72·07°/₀ of platinum in the 17·894 grams of material analyzed. For the purpose of comparison, platinum contents of samples of platinum bearing material from different parts of the world are given : The analyses are by Messrs. Deville and Debray ; Oregon, 51·45 °/₀ ; Australia, 61·40 ; California, 85·50 ; Choco, Columbia, 86·20 ; Nischne Tagilsk, Urals, 76·40.

The following is a list of Canadian localities at which the occurrence of platinum has been noticed. With the exception of that at Sudbury, Ont., all the finds have been made in the alluvial deposits, usually while working for gold.

Rivière du Loup, and Rivière des Plantes, province of Quebec. (See note above.)

PLATINUM.
Occurrences.

Sudbury, Ontario.—This occurrence is one of the very few in the world where platinum is found "in situ."—In this case the metal is found in combination with arsenic and associated with the nickeliferous pyrrhotite deposits. The arsenical platinum mineral was named sperrylite by H. A. Wells who described it, and found it to consist on analysis of: Platinum 52. 57 per cent; Rhodium 0.72; Antimony 0.50; Arsenic 40.98; Iron 0.07; Tin oxide 4.62.

At Sudbury the ore bodies consist of chalcopyrite and nickeliferous pyrrhotite, which are primarily worked for their nickel and copper contents, and yield a large proportion of the world's supply of nickel. The ore undergoes a first treatment at the mines, where it is smelted, the low grade matte first made containing approximately 15 per cent of nickel and about the same proportion of copper and the Bessemerized matte from 35 to 40 p.c. of nickel. This is shipped to the refinery in New Jersey where it is finally treated. According to a reliable authority this matte holds 1.25 oz. of the platinum metals per ton of nickel contents of the matte, and of this some 80 per cent is extracted. In 1900 the matte shipped from Sudbury, contained approximately 4,594 tons of nickel. The platinum metals would therefore, on that basis have amounted to 5,742 oz. This however is not included in the table of production, as returns of platinum from this source are not sent in to the Mines Section.

North Saskatchewan, N.W.T. Native platinum has been found in association with gold on the bars in the North Saskatchewan river, in the neighborhood of Edmonton, district of Alberta. A sample of the material from this locality received from Mr. Pearce consisted of exceedingly minute rounded and flattened grains of native platinum, the largest not exceeding one fourth of a millimeter in diameter, with intermixed, equally minute scales of native gold. (Geol. Surv. Rep. 90-91 part R).

Yukon river and tributaries, Y. T. Platinum was reported to have been found in small quantities along all or nearly all tributaries of the Yukon in association with river-bar gold (Geol. Surv. Rep. 87-88). but these reports have not been verified by fuller investigation and it is still uncertain whether this metal has been discovered or not on the Yukon river.

It has been reported lately that comparatively large quantities of platinum were bought at low prices from placer miners in the Yukon, who were ignorant of its value, and sold again at a large profit in Vancouver.

PLATINUM.
Occurrences.

Teslin (Hootalinqua river), Y.T.—A discovery of platiniferous sand was made in 1898, at the mouth of the Hootalinqua river and on Thirty Mile (Lewis) river. A company was said to have been subsequently organized to work these alluvions for the gold and platinum, by means of dredges.

Upper Similkameen and Tulameen rivers, British Columbia, especially on Granite, Cedar and Slate Creeks. (See note above.)

Tranquille river, B. C. This river which flows into Kamloops lake, was worked before 1862 by gold miners; later the work was taken up by Chinamen. Gold is found for a distance of eight miles from the mouth. The metal is scaly and mixed with it are particles of platinum, similar in shape and size to those of gold.
(Geol. Surv. Rep. 1877-1878 part B.)

Fraser river, British Columbia. Found in small quantities in fine scales, with gold, particularly at a place ten miles below Lillooet. (Geol. Surv. Rep. 87-88).

A sample of crude platinum sand from washings in the Fraser river gave the following result:—

Base metals	6·48°/₀
Platinum group	81·30
Osmiridium	12·20

Rock creek, Camp McKinney, Yale district, B.C. A sample of heavy black sand taken from the riffles of sluice-boxes at Camp McKinney, Rock creek, a tributary of Kettle river which contained in addition to gold a large proportion of native platinum, gave on analysis the following results:

Native platinum	44·7
Gold	1·8
Magnetite	47·4
Quartzose sand	6·1

The platinum was in the form of exceedingly minute to moderately coarse irregularly shaped grains, the largest of which measured four millimeters in diameter. (Geol. Surv. Rep. 92-93).

North Thompson and Clearwater rivers, B.C. The discovery of platinum in the North Thompson and Clearwater rivers has created some interest, as its existence was not formerly suspected. It is found associated with the alluvial gold but the extent and condition of the finds are not yet fully determined. (Rep. Minister of Mines, B.C., 1900).

SOURCES OF THE WORLD'S SUPPLY. OCCURRENCE AND TREATMENT.

Although platinum is known to occur in situ in several places, it is in such small quantities, that nowhere are these occurrences worked for the metal. These deposits have therefore at present no direct economic value although their study may eventually throw light on the origin of this metal which so far is not well understood. Platinum has been found in place (in contradistinction to alluvial deposits) in the following countries, a short description being given in each case.

Columbia.—In Columbia the platinum deposits may be divided into two main classes, the more recent alluvial deposits and the "caliche" beds. These last are deposits which consist of clay, sand and boulders indiscriminately mixed and which show no stratification. Those deposits are probably of glacial origin, and are the oldest platiniferous deposits of El Choco. They frequently contain diorite boulders, and it seems possible that the platinum will eventually be found disseminated in this rock. The true gravel deposits of El Choco are newer than the "caliche' beds and in part derived from them. The largest deposits of the kind are situated along the Tamana, Iro, and San Juan rivers. These are from 6 to 20 feet deep and have been extensively worked by the natives. (Min. Ind. Vol. I.) Although the caliche" beds cannot be said to contain platinum in situ, yet the occurrence differs from the ordinary alluvial deposits. The annual production of Columbia has varied for the last few years between 10,000 and 12,000 oz.

New South Wales.—In New South Wales platinum is said to have been detected in felsite and granite at Broken Hill. It is, of course, very sparsely disseminated. It has also been found in small quantities in washings for gold at several places, and since 1894 there is a production recorded, which is very irregular and varies between 500 and 2,000 ozs. annually.

Brazil.—In Brazil platinum is found associated with gold in quartz lenses intercalated in gneiss and schists.

United States.—As to the United States, Mr. David T. Day in a paper read before the American Institute of Mining Engineers in February 1900 makes the following statement:

" Messrs. William E. Hidden and J. H. Pratt have found sperrylite-platinum arsenide in placers at several points in the Cowee valley of North Carolina. The conditions favour the belief that the source of this mineral is a ledge of impure rhodonite and biotite, containing

PLATINUM.

much disseminated iron sulphides, conditions much like those at Sudbury, Canada.

"There have been unsubstantiated reports of the occurrence of platinum in place in certain localities of the Catskills in New York, in granite near Philadelphia, and again near Port Deposit, Maryland."

As to alluvion deposits he says:

"Platinum has been found at many places on the Pacific beach, from as far south as San Bernardino county, northward to the mouth of the Columbia. Indefinite reports have been made of its occurrence further north on the Washington beach; but its amount is certainly not great. The principal beaches where platinum has been reported, beginning at the south, are: Santa Barbara, Lampoc, the beaches of San Luis, Obispo county; Santa Cruz, and occasionally between Santa Cruz and the Golden Gate. In accordance with Blake's statement, the richest beaches are further north, in Humboldt and Del Norte Counties. The beach mines of Gold Bluff north of Arcata, Big Lagoon, Stone Lagoon, Little River, Crescent City, Cal., and Gold Beach and Port Orford, in Curry county Oregon, have all yielded platinum in commercially appreciable quantities. Still further north, platinum is found at Yaquina beach, Oregon, but the sands there are poor."

Russia.—The metal is found in the Ural mountains sparsely disseminated in peridotite and serpentine masses. The platiniferous alluvial deposits are also characterized by the presence of boulders of olivinite and serpentine, which both contain chromite. Thus the source may be said to have been placed, the matrix being beyond doubt the serpentintized olivinite. It is even reported that a streak or zone of this rock some six feet wide in a massive olivinite, was actually worked for some time for its contents of platinum, but at a depth of about 35 feet it was no longer workable. It does not seem certain that platinum has been found in the perfectly fresh igneous rock which had not yet undergone serpentinization, hence there is a possibility that the same agencies that brought about the conversion of the olivine into serpentine also introduced the platinum into the rock. (Min. Ind. Vol. VI. Abstract.)

Over 90 per cent of the world's production of platinum is derived from the placer deposits of the Urals in Russia. The whole of the platinum producing portion of these mountains is contained within a length of 100 miles along the 60° meridian E. of Greenwich, between latitudes 57.30° and 59° and is all included within the government of Perm. Within this area there are two chief districts, Goroblagodatsk in the north and Nishni Tagilsk in the south. The platinum

PLATINUM.

placers occupy the valley bottoms of a number of streamlets and their branches, the alluvions of the larger streams being rarely rich enough for working. In the Goroblagodatsk district, which lies wholly on the Asiatic side of the Urals, the placers are found on the river system of the Iss and its tributaries which, in its turn, discharges into the Tourna. The total length of the Iss and its affluents is about 60 miles.

In the southern district the main producing area lies on the European side of the Ural watershed in the river systems of the Vissine and the Martian. On these 18 placers are being worked. On the Asiatic side there are three fields of operation on the Chornaia and its tributary, the Chonge.

The platiniferous alluvion is very variable in thickness and in richness, but always shallow, the placers being undoubtedly of quaternary age. These placers carry gold in addition to the platinum, but these metals did not occur together in primary deposits, and their presence together is due to the fact that the stream which formed the alluvial deposit, received the product of disintegration of rocks containing gold and of rocks containing platinum, the source of gold being traceable to quartz veins or to rocks of an acid type, whereas the platinum is derived from basic rocks.

The thicknessess of the respective layers of overburden and platiniferous alluvion are also recorded, and are as follows: Overburden average 16 feet (maximum 63 feet, minimum 2½ feet), pay gravel, average 3½ feet (maximum 6 feet, minimum 1 foot). The average richness of these pay-sands being at present about 2 dwt., crude, to the ton. The yield of platinum to the ton of gravel washed was at first much higher, but has decreased considerably within recent years. According to private records the sands of the Gorablagodatsk district in 1870 yielded 1 oz per ton, in 1882 this fell to 9 dwt., in 1886 to 4½ dwt. and in 1895 it was 1½ dwt. In the Nishni Tagilsk district, the same decrease is noticeable. This progressive impoverishment is due to the fact that at first only the small shallow and rich placers at the headwaters of the smaller streams were worked; and as these were exhausted, gradually poorer and poorer deposits further down stream had to be attacked, till now there is nothing left but the more extensive low grade placers in the large valleys and the tailings of earlier washings.

Crude platinum, as obtained by washing of the gravels, is in the form of fine particles, grains and scales, of about the size of the finest gunpowder; its colour varying from light to very dark grey. Nuggets

PLATINUM.

are occasionally met with, the largest found in the Gorablagodatsk district was 72½ ozs, and in the Nishni Tagilsk 310 ozs.

Methods of Working.—The method of working the placer gravels is almost everywhere identical. There are two different labour systems in force in all the alluvial workings of Russia. The men are either day labourers receiving regular wages, or they are 'starateli' or free labourers. These latter are what the Cornish miner would call 'tributers'; they are allowed to work certain portions, in some cases the whole of a placer, practically as they please, and are in turn bound to sell the platinum they produce, to the individual or company owning the placer, at a fixed price, which is usually less than half its value. These men are said to be able to work gravels too poor to be worked by day wages.

The method of working adopted by tbe 'starateli' is simple in the extreme; they establish a short sluice-box or 'tom' in some position where they can run a stream of water into the head of the box. One of the most usual types of sluice used in the Urals consists of a box about 2 feet wide, into which the gravel is dropped, and through which a current of water is run. The stream of gravel and water is carried into the sluice proper, which consists of a box, some two feet wide by 30 feet long, inclined at a low angle (about 5°). The far end is opened and terminates in a chute under which a cart can stand to receive the boulders and large pebbles. On the bottom of this sluice, at intervals of about 7 feet, there are three openings which are 9 inches by two feet (the width of the box). These openings are grated with bars of iron set ½ inch apart, and through these, practically all the finer sand and water drop, whereas the larger stones continue on to the chute. Beneath each grating runs a transverse box to receive the sand and water which drop through the gratings. These boxes are also inclined at a low angle and deliver into a trough which lies at a steeper angle; this trough carries the sands, which are now considered worthless, into a settling box, whereas the water runs off into the ditch. The sands are shovelled from the settling box into carts for removal. The bottoms of the main sluice of the transverse boxes, and of part of the trough are covered with riffles and coarse matting, forming interstices for catching the heavy sand. As will be seen, this sluice is really the hydraulic miners sluice, undercurrent and grizzly in miniature. In some places this sluice is combined with a simple machine for disintegrating clayey gravels. When the work is done on an extended scale either by a large company of starateli or by mine owners, washing machines are built and the pay gravels are brought to them in small carts drawn by one horse. The machines are usually driven by steam. One type of washing machine consists of a cylindrical tub, the bottom of which is a circular cast iron pan 15 inches deep, pierced with $\frac{5}{8}$ inch holes; around the top of the pan runs an annular cast iron pipe, perforated so as to allow water in small jets to play into the pan. In the centre is a vertical shaft carrying a six-armed spider, from each of the arms of which hang a couple of iron bars that almost touch the bottom of the pan. The shaft is revolved at about 25 revolutions per minute, and the gravel is fed in continuously. The large stones which remain after the disintegration are removed from time to time, while the sands and clayey matter suspended in water pass through the perforated bottom and fall upon a sloping board covered with stout sheet iron which discharges into a large box, the front of which is closed by a strong wooden grating kept always padlocked while the machine is in operation. The bottom of the box is inclined at an angle of about 15°. It is eight feet wide and the bottom is covered by stout bass mats, which are held in place by stout pieces of wood about 3 inches deep, which are kept in their places by wedges, and act as riffles. The sands drop through the grating into a transverse shallow trough, then over a table some 18 feet long and furnished with wooden riffles and one or two more troughs. At the bottom of the table the sands drop into a wooden chute which is at such a height above the ground that these sands can be carried by the stream of water to a low dump, some 100 yards away from the machine.

PLATINUM.

It is evident that any coarse pieces of platinum or nuggets which are the most liable to be stolen, will be retained in the padlocked section of the table, while most of the finer platinum sands are also caught in the mats; the lower table is said to catch very little, but this however is no proof that the tailings are clean, for all the arrangements now in use are obviously unsuitable for catching flour platinum. The machine referred to above can treat about 100 tons in 12 hours, the volume of water required being from 5 to 10 times that of the gravel. The clean-up of the different appliances usually takes place every 12 hours at 5 p.m. and 5 a.m. The sands resulting from the clean-up are then further concentrated in another very simple sluice, consisting of an upper portion in the shape of a box lined with sheet iron and a lower portion which consists of a narrow box about 15 feet long which is laid with well washed peats forming shallow riffles. The sands are thrown in small quantities into the box and then worked about with a hoe or a narrow shovel in a carefully regulated current of water; the bulk of the platinum is retained in the box, the rest being caught in the riffles and most of the lighter mate-

PLATINUM.

rial is carried away. The rich concentrates thus obtained, seem to consist of crude platinum, chromite and a few of the heavier minerals. They are finally cleaned on a small flat table or wash-board. This consists of two tables separated by a drop of two inches. Above the upper one is a small box which delivers a regular shallow stream of water over the whole breadth of the table, the force of the current being just sufficient to move the average-size particles of platinum. The breadth of the board is about 3 feet. The concentrated sands from the sluice are thrown on the upper table and are continually pushed upward against the current by means of a little wooden hoe. On this table the concentration is finished; the sands are worked with the hoe until fairly clean and are then allowed to be carried by the stream of water to the lower table, where the washing is completed. The clean platinum sands are then collected off both tables and stirred up with sufficient mercury to dissolve any gold that may be present. The platinum left behind is now ready for the market. In its crude state it usually contains from 75 to 85 per cent of pure metal. It is then ready to be sold to the refineries. The bulk of the produce of Russia is exported in the crude state.

In *Columbia*, which is the platinum producer next in importance to Russia, the metal is also recovered by very simple methods. The greater proportion is obtained from the working of the "caliche" beds which are usually ground-sluiced. River bars and beds are worked in even a more primitive way; women diving for the black sand and washing it in pans.

PRECIOUS METALS.

PRECIOUS METALS.

The precious metals, gold and silver, are considered together, following the custom of past years.

Gold.

GOLD.

Production.

The production of gold in Canada in 1901 was $24,128,503, a decline as compared with the previous year of $3,779,652. This is the first time in ten years that the production has not shown an increase. This is mostly due to the fact that the output of 1901 of the Yukon, was less than in 1900 by $4,275,000, this falling away being

PRECIOUS METALS.
Gold.
Production.

offset in a small degree by a steady increase in the British Columbia production. It was only to be expected that as the richer parts of the more easily worked shallow placer ground became exhausted the production should show a falling off. With the gradual introduction however of more elaborate and through methods for mining the poorer parts of the gravels, and with the discovery and working of quartz, deposits a gradual increase in the output should set in, thus repeating the history of most districts on the continent starting in a similar way. Nearly 79 per cent of the production of the whole of Canada in 1901 was derived from placer diggings, as compared with 84 per cent in 1900, while the proportion of the output from lode mines increased from 16 per cent to 21 per cent. The output from lode mines in 1900 was $4,349,492 and in 1901 $5,143,403. The placer output in 1901 was $18,985,100 of which $18,000,000 came from the Yukon and the balance, with the exception of a small quantity from the Saskatchewan river, was obtained from British Columbia.

The various provinces contributed to the total in 1901 in about the following proportions. Yukon district 75 per cent, British Columbia 22 per cent, Nova Scotia 2 per cent, and Ontario 1 per cent.

TABLE 1.

PRECIOUS METALS.

GOLD—ANNUAL PRODUCTION IN CANADA.

Calendar Year.	*Ounces. Fines.	Value.
1887	57,465	$ 1,187,804
1888	53,150	1,098,610
1889	62,658	1,295,159
1890	55,625	1,149,776
1891	45,022	930,614
1892	43,909	907,601
1893	47,247	976,603
1894	54,605	1,128,688
1895	100,806	$ 2,083,674
1896	133,274	2,754,774
1897	291,582	6,027,016
1898	666,445	13,775,420
1899	1,028,620	21,261,584
1900	1,350,176	27,908,153
1901	1,167,320	24,128,503

Calculated from the value at the rate of $20.67 per ounce.

PRECIOUS METALS.
Gold.

Production

TABLE 2.

PRECIOUS METALS.

GOLD:—PRODUCTION BY PROVINCES AND DISTRICTS, CALENDAR YEAR 1901.

Provinces.	*Ounces. Fine.	Value.
Nova Scotia	(b) 26,462	$ 546,963
Quebec	(b) 145	3,000
Ontario	(b) 11,845	244,837
North west Territories—		
Yukon District	(a) 870,827	18,000,000
Saskatchewan river	(a) 726	15,000
British Columbia	(c 257,315	5,318,703
Total	1,167,320	$24,128,503

* Calculated from the value at the rate of $20.67 per ouuce.

(a) Placer gold.

(b) Gold from vein mining.

(c) As follows: Gold from placer mining. .... $ 970,100
" vein " 4,348,603
$5,318,703

Nova Scotia.

NOVA SCOTIA :—

The gold output of this province is obtained entirely from free-milling quartz ores and the production has never reached very large proportions, having varied for many years between quarter and a half million dollars.

The statistics of gold-production are given in Tables 3, 4, 5 and 6. Table 3 shows the annual gold output, Table 4 the tons of quartz crushed, and the average yield per ton, in Table 5 the total product of each district from 1862 to the end of 1901 is exhibited as well as the average yield per ton, and Table 6 shows the amount of ore crushed and the yield per district for 1901.

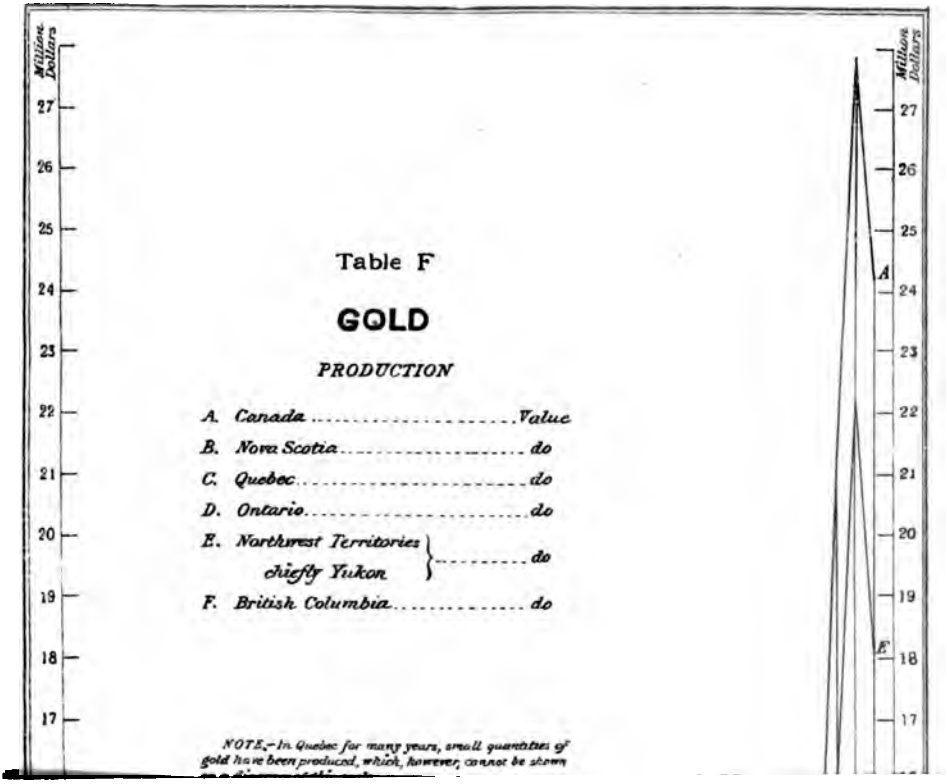

Table F

GOLD

PRODUCTION

NOTE.—In Quebec for many years, small quantities of gold have been produced, which, however, cannot be shown

PRECIOUS METALS.

Gold.

Production.

Nova Scotia.

TABLE 3.

PRECIOUS METALS.

GOLD:—NOVA SCOTIA—ANNUAL PRODUCTION.

Calendar Year.	Value.	Calendar Year	Value.
1862	$141,871	1882	$275,090
1863	272,448	1883	301,207
1864	390,349	1884	313,554
1865	496,357	1885	432,971
1866	491,491	1886	455,564
1867	532,563	1887	413,631
1868	400,555	1888	436,939
1869	348,427	1889	510,029
1870	387,392	1890	474,990
1871	374,972	1891	451,503
1872	255,349	1892	389,965
1873	231,122	1893	381,095
1874	178,244	1894	389,338
1875	218,629	1895	453,119
1876	233,585	1896	493,568
1877	329,205	1897	562,165
1878	245,253	1898	538,590
1879	268,328	1899	617,604
1880	257,823	1900	598,553
1881	209,755	1901	546,963

TABLE 4.

PRECIOUS METALS.

GOLD:—NOVA SCOTIA, ORE TREATED AND YIELD OF GOLD PER TON.

Calendar Year.	Tons Treated.	Yield of Gold per Ton.	Calendar Year.	Tons Treated.	Yield of Gold per Ton.
1862	6,473	$21·91	1882	21,081	$13·04
1863	17,000	16·02	1883	25,954	11·60
1864	21,431	18·21	1884	25,186	12·44
1865	24,421	20·32	1885	28,890	14·98
1866	32,157	15·28	1886	29,010	15·70
1867	31,384	16·96	1887	32,280	12·81
1868	32,259	12·41	1888	36,178	12·08
1869	35,144	19·91	1889	39,160	13·02
1870	30,824	12·56	1890	42,749	11·11
1871	30,787	12·17	1891	36,351	12·42
1872	17,089	14·94	1892	32,552	11·98
1873	17,708	13·05	1893	42,354	8·99
1874	13,844	12·87	1894	55,357	7·04
1875	14,810	14·76	1895	60,600	7·47
1876	15,490	15·08	1896	69,169	7·13
1877	17,369	18·95	1897	73,192	7·68
1878	17,989	13·63	1898	82,774	6·50
1879	15,936	16·83	1899	112,226	5·50
1880	13,997	18·42	1900	87,390	6·85
1881	16,556	12·66	1901	91,948	5·32

PRECIOUS METALS.

Gold.

Production.

Nova Scotia.

TABLE 5.

PRECIOUS METALS.

GOLD:—NOVA SCOTIA.—PRODUCTION OF THE DIFFERENT DISTRICTS FROM 1862 TO 1901, INCLUSIVE.

Districts.	Tons of Ore Crushed.	Total Yield.				Average Yield per Ton of 2,000 lbs.
		Oz.	Dwt.	Grs.	Value at $19.00 per oz.	
					$	$ c.
Brookfield	60,474	28,055	13	22	533,058	8·81
Caribou	137,036	45,958	12	21	873,214	6·37
Central Rawdon	13,340	10,121	11	21	192,310	14·42
Fifteen-mile Stream..	40,280	18,132	13	5	344,520	8·55
Killag.	1,291	1,967	8	12	37,381	28·95
Lake Catcha....	17,018	13,920	7	22	264,487	15·54
Malaga..............	24,617	17,261	3	4	327,962	13·32
Montague	25,878	40,005	10	—	760,105	29 37
Oldham...........	49,537	53,293	13	10	1,012,580	20·44
Renfrew.............	49,945	41,868	16	12	795,508	15·93
Salmon River	103,602	33,898	6	21	644,068	6·22
Sherbrooke..........	264,131	148,477	5	13	2,821,068	10·68
Stormont....	245,409	78,750	16	21	1,496,266	6·10
Tangier......	38,257	22,498	5	2	427,467	11·17
Uniacke.............	58,192	39,988	15	8	759,787	13.06
Waverly.............	188,990	66,112	9	15	1,256,137	9·04
Wine Harbour.......	55,335	35,422	13	6	673,031	12·16
Whiteburn..........	7,378	10,218	18	20	194,160	26·32
Other districts.......	83,807	58,209	19	17	1,105,990	13·20
	1,414,517	764,163	2	12	14,519,099	10·26
From tailings, &c....		463	9	2	8,806	
		764,626	11	14	14,527,905	

PRECIOUS METALS.

Gold.

Nova Scotia.

TABLE 6.

PRECIOUS METALS.

GOLD :—NOVA SCOTIA, DISTRICT DETAILS—CALENDAR YEAR, 1901.

Districts.	Mines.	Mills.	Tons of Ore Crushed.	Total Yield of Gold.			Average Yield of Gold per Ton.		
				Oz.	Dwt.	Grs.	Oz.	Dwt.	Grs.
Blockhouse	1	2	465	808	..	..	1	14	18
Brookfield	1	1	7,515	2,834	4	..		7	13
Caribou	5	6	7,037	2,027	1	1	..	5	18
Harrigan Cove	2	3	4,167	2,595	6	9	..	12	11
Lake Catcha	3	3	1,855	973	2	..	..	10	12
Leipsigate	1	2	1,286	604	14	5	..	9	10
Malaga Barrens	1	1	349	320	9	7	..	18	9
Mills Village	1	1	642	520	..	..	..	16	5
Montague	*	3	380	349	14	9	..	18	11
Oldham	2	1	640	364	2	10	..	11	9
Renfrew	2	2	650	1,694	9	..	2	12	..
Sherbrooke	2	3	17,391	2,985	16	3	..	3	10
Stormont	3	4	29,664	5,592	10	..	..	3	18
Tangier	1	1	536	201	5	..	..	7	12
Uniacke	3	4	1,736	940	..	..	..	10	19
Waverly	2	2	12,523	3,044	10	12	..	4	21
Wine Harbour	2	3	3,955	1,269	16	12	..	6	10
Other districts	7	10	1,157	460	18	..	..	7	23
Total	†42	52	91,948	27,585	18	20	..	5	11
Mortared	....	....	....	37	12	17	....		
Cyanide process (Tailings)	....	2	7,445	425	16	9	....		
Total	....	....	......	28,049	7	22	.. ..		

* Tributers, &c. † Approximate.

Quebec.

QUEBEC.

No returns of production from placer deposits were received for 1901. The small output of $3,000, credited to this province represents

PRECIOUS METALS.

Gold.

Quebec.

values recovered from the pyrites mined primarily as sulphur ores in the Eastern Townships.

TABLE 7.

PRECIOUS METALS.

GOLD—QUEBEC—ANNUAL PRODUCTION.

Calendar Year.	Value.	Calendar Year.	Value.
1877	$12,057	1890	$1,350
1878	17,937	1891	1,800
1879	23,972	1892	12,987
1880	33,174	1893	15,696
1881	56,661	1894	29,196
1882	17,093	1895	1,281
1883	17,787	1896	3,000
1884	8,720	1897	900
1885	2,120	1898	6,089
1886	3,981	1899	4,916
1887	1,604	1900	Nil.
1888	3,740	1901	3,000
1889	1,207		

Ontario.

ONTARIO.

Production of gold in Ontario in 1901 amounted to only $244,837, of which $131,044, was obtained from the Belmont, Deloro and Gatling Five Acres mines in Peterborough and Hastings, counties the balance having been derived from the mines of north-western Ontario, more particularly from the Mikado, Sultana, and Sakoose.

TABLE 8.

PRECIOUS METALS.

GOLD—ONTARIO—ANNUAL PRODUCTION.

Calendar Year.	*Ounces. (fine).	Value.
1887	327	$ 6,760
1888		
1889		
1890		
1891	97	2,000
1892	344	7,118
1893	708	14,637
1894	1,917	39,624
1895	3,015	62,320
1896	5,563	115,000
1897	9,158	189,294
1898	12,864	265,889
1899	20,395	421,591
1900	14,392	297,495
1901	11,845	244,837

* Calculated from the value at $20·67 per ounce.

PRECIOUS METALS.

Gold.

North-west Territories.

NORTH-WEST TERRITORIES.

The gold fields of the North-west Territories, to which attention has so far been chiefly directed are confined, to the alluvial workings of the Saskatchewan river, and those of the Yukon river and its tributaries. The difficulty of obtaining anything like accurate statistics of the output, from such deposits as these, where thousands of men are independently engaged in mining the precious metal, will be easily recognized. Much of the Saskatchewan river gold, finds its way to the local banks and a basis for an estimation of the product is thus found, while the greater part of the Yukon gold is ultimately sold at the different receiving offices of the United States mint. The receipts of these offices, taken in conjunction with careful estimates by government officers, bank managers, and transportation companies at Dawson, furnish a means of estimating the Yukon output, probably as accurately as it is possible to obtain it.

Statistics of production in the district since 1887 are shown in Table 9.

TABLE 9.

PRECIOUS METALS.

GOLD—NORTH-WEST TERRITORIES—PRODUCTION.

Calendar Year.	Yukon District.		Saskatchewan River.	
	*Ounces. (fine).	Value.	*Ounces (fine).	Value.
		$		$
1885 } 1886 }	4,838	100,000	....	....
1887	3,387	70,000	102	2,100
1888	1,935	40,000	58	1,200
1889	8,466	175,000	968	20,000
1890	8,466	175,000	194	4,000
1891	1,935	40,000	266	5,500
1892	4,233	87,500	508	10,506
1893	8,515	176,000	466	9,640
1894	6,047	125,000	725	15,000
1895	12,095	250,000	2,419	50,000
1896	14,514	300,000	2,661	55,000
1897	120,948	2,500,000	2,419	50,000
1898	483,793	10,000,000	1,209	25,000
1899	774,069	16,000,000	726	15,000
1900	1,077,649	22,275,000	242	5,000
1901	870,827	18,000,000	726	15,000
Total	3,401,717	70,313,500	13,689	282,946

*Calculated from the value at $20.67 per ounce.

PRECIOUS Territories.

A statement compiled in the Timber and Mines branch, and published in the report of the Department of the Interior showing the total gold production, the total exemption, the total amount upon which the royalty was collected and the amount of royalty paid, as shown by returns from May 1st 1898 to June 30th 1901 is given below. Comparison with Table 9 will show that quite a large proportion of the Yukon output escaped the royalty dues.

MONTH.	Total Gold Production.	Total Exemption.	Royalty Collected on.	Royalty Paid.
1898.	$ cts.	$ cts.	$ cts.	$ cts.
May	45,277 00	10,850 00	34,427 00	3,442 70
June	3,027,496 20	342,550 00	2,698,501 20	269,850 12
Two months	3,072,773 20	353,400 00	2,732,928 20	273,292 82
July	928,818 00	135,000 00	793,818 00	79,381 80
August	395,045 50	140,000 00	255,045 50	25,504 55
September	251,547 70	64,540 00	187,007 70	18,700 75
October	13,669 65	2,496 00	11,173 65	1,117 37
November	4,851 56	2,912 00	1,939 56	193 95
December	8,719 55	624 00	8,095 55	809 55
Six months	1,602,651 96	345,572 00	1,257,079 96	125,707 97
1899.				
January	6,552 76	4,784 00	1,768 76	176 94
February	4,868 29	624 00	4,244 29	424 41
March	15,431 40	3,952 00	11,479 40	1,147 93
April	43,889 57	15,400 00	28,489 57	2,848 92
May	844,606 18	180,703 00	663,903 18	66,390 28
June	5,064,282 86	1,148,622 02	3.915,660 84	391,565 92
Six months	5 979,631 06	1,354,085 02	4,625,546 04	462,554 40
July	664,205 72	208,380 82	455,824 90	45,582 49
August	1,521,708 96	311,740 16	1,209,968 80	120,996 88
September	924,907 09	187,413 99	737,493 10	73,749 31
October	371,947 82	63,863 02	308,084 80	30,808 48
November	176,599 48	29,088 48	147,511 00	14,751 10
December	84,531 76	31.976 26	52,565 50	5,255 55
Six months	3,743,900 83	832,462 73	2,911,438 10	291,143 81
1900.				
January	....	....	....	....
February	42,179 62	19,333 22	22,846 40	2,284 64
March	96,968 23	42,500 33	54,467 90	5,446 79
April	59,839 70	21,667 80	38,171 90	3,817 19
May	796,866 25	313,642 65	483.223 60	48,322 36
June	5,069,710 01	1,272,137 91	3,797,572 10	379,757 21
Six months	6,065,563 81	1,669,281 91	4,396,281 90	439,628 19

Precious Metals.

Gold.

North-west Territories.

Month.	Total Gold Production.	Total Exemption.	Royalty Collected on.	Royalty Paid.
1900.	$ cts.	$ cts.	$ cts.	$ cts.
July	2,346,440 64	410,399 99	1,936,040 65	193,707 36
August	1,354,543 88	137,500 00	1,219,148 10	121,914 81
September	1,012,731 48	91,100 00	921,630 90	92,163 09
October	378,991 50	40,000 00	338,990 17	31,772 73
November	63,591 79	38,500 00	25,091 79	2,509 15
December	14,595 47	....	14,595 47	1,459 54
Six months	5,170,894 76	717,499 99	4,455,497 08	443,526 68
1901.				
January	28,486 81	10,000 00	18,486 81	1,832 65
February	34,923 53	10,000 00	24,923 53	2,492 34
March	13,651 91	2,500 00	11,151 91	1,115 23
April	65,156 32	5,000 00	60,156 32	6,015 63
May	183,953 75	40,833 33	143,119 67	10,728 39
June	3,665,015 71	1,141,833 30	2,523,182 41	126,950 06
Six months	3,991,188 03	1,210,166 63	2,781,020 65	149,134 30

BRITISH COLUMBIA.

British Columbia.

$5,318,703 in gold was produced from the mines of British Columbia in 1901 of which amount 18 per cent or $970,100 was obtained from placer workings and $4,348,603 from lode mining.

Statistics of production are given in Tables 10 and 11.

TABLE 10.

PRECIOUS METALS.

GOLD—BRITISH-COLUMBIA—ANNUAL PRODUCTION.

Calendar Year.	Value.
	$
1858	705,000
1859	1,615,072
1860	2,228,543
1861	2,666,118
1862	2,656,903
1863	3,913,563
1864	3,735,850
1865	3,491,205
1866	2,662,106
1867	2,480,868
1868	2,372,972
1869	1,774,978
1870	1,336,956
1871	1,799,440
1872	1,610,972
1873	1,305,749
1874	1,844,618
1875	2,474,904
1876	1,786,648
1877	1,608,182
1878	1,275,204
1879	1,290,058
1880	1,013,827
1881	1,046,737
1882	954,085
1883	794,252
1884	736,165
1885	713,738
1886	903,651
1887	693,709
1888	616,731
1889	588,923
1890	494,436
1891	429,811
1892	399,525
1893	379,535
1894	530,530
1895	1,266,954
1896	1,788,206
1897	2,724,657
1898	2,939,852
1899	4,202,473
1900	4,732,105
1901	5,318,703

PRECIOUS METALS.

Gold.

British Columbia.

TABLE 11.

PRECIOUS METALS.

GOLD—BRITISH COLUMBIA—PRODUCTION BY DISTRICTS—1901.

DISTRICTS.	GOLD, PLACER.		GOLD, LODE.	
	Ounces.	Value.	Ounces.	Value.
				$
Cariboo:				
Cariboo Division.......... .	13,980	279,600	....	....
Quesnel "	12,000	240,000	....	....
Omineca "	955	19,100	....	....
Cassiar:				
Atlin Lake Division........	15,000	300,000	....	....
All other.......	1,140	22,800	5	103
East Kootenay:				
Fort Steele Division........	630	12,600	....	....
Other Divisions............	40	800	....	....
West Kootenay:				
Ainsworth Division.........	....	....	63	1,312
Nelson "	....	....	32,868	679,340
Slocan "	....	.. ..	244	5,043
Trail Creek "	....	....	132,333	2,735,323
All other..............	100	,000	234	4,837
Lillooet.	1,304	26,080	1,079	22,303
Yale:				
Grand Forks &c......	250	5,000	37,388	772,810
Similkameen Division......	234	4,680	....	....
Yale "	2,272	45,440	18	370
Coast and other Districts......	600	12,000	6,152	127,162
Total	48,505	970,100	210,384	4,348,603

The main features concerning the progress of gold mining in British Columbia during the year are well summarized by Mr. W. F. Robertson the Provincial Mineralogist in the report of the Minister of Mines for the province as follows:—

Placer Mining:—"The placer gold output for the year 1901 was $970,100, a decrease from the previous year of $308,624. This is accounted for by the fact that the Atlin production has again suffered a serious diminution; the ordinary placers are mostly worked out, and the hydraulic companies which should have been at work making an output, have managed to get into litigation among themselves and with individual miners so that the season was practically lost. It is hoped and expected that by next season the existing plants, and those now under construction, will be able to work, and if so, the output of the camp will certainly be doubled."

PRECIOUS METALS.

Gold.

British Columbia.

"The Cariboo district shows a considerably decreased production, which is due almost entirely to the small output of the largest company in the district, the Cariboo Consolidated, which through shortage of water, was only able to work a part of the season. This shortage of water was occasioned by the sudden melting of the snow in the spring, leaving insufficient water for the latter part of the season. The snow usually retained on the mountains is, as a rule, a sufficient reserve supply to last through the season, but last year this all melted at once causing spring freshets and a dry summer season. The smaller companies in the district did well, and with a normal snowfall and spring all should make a very good showing next season.

"A small output has been made from the Liard division, but as last year was the first year of the operations of the hydraulic companies there, most of the work was preparatory and of the nature of development.

"On the coast certain deposits of black sand have been worked to a profit but have not made the output expected.

"Dredging for gold, although it continues to receive much attention and large amounts have been invested in capital, has not as yet yielded any very material return or output. That the gold exists in the beds of many of the rivers in considerable quantities has been conclusively proved many times, but the difficulty seems to be to save it.

"It might be pointed out that in every instance, as far as is known, the dredges operating in British Columbia, work up stream and it is very questionable if such a practice is best suited to the conditions here prevailing, or whether they should not, on the contrary, work down stream.

"In most of our rivers, dredging is done under the following conditions, viz.: a swift current, numerous boulders, fine flaky gold to be recovered, and finally, a hard undredgeable and uneven bedrock.

"It is submitted that under these conditions, a dredge working up stream cannot be expected to save or take up all the gold. The agitation of the river bed by the buckets is great, and the gold will and is bound to settle into crevices in the bedrock. A very small crevice may hold the profits of a month, from which in a hard bedrock it is impossible for a dredge to recover it. Any gold, once raised and afterwards dropped, is swept by the force of the current back of the dredge and bucket and is consequently lost. On the other hand, in working down stream a 'face' is formed, which will be more or less inclined; the gold is swept from the bedrock on to this inclined face of removable material and would be taken up in a subsequent bucket load.

PRECIOUS METALS.

Gold.

British Columbia.

"*Lode Gold Mining.*—Placer mining is of necessity, dependent on the weather, and is as variable in this province as that commodity, but in lode gold mining, as the mines develop, the output becomes as regular as the output of a manufacturing business, and it is to lode mining that the province is indebted for its ever increasing gold production. In 1901 the lode mines of the province produced $4,348,603 in value of gold, an increase over the previous year of $895,222 or 26°/o. When it is remembered that this increase follows an increase in 1899 of about 30°/o and in 1900 of 21°/o, a fair idea may be formed of the development and growth of the industry. This great increase is due first and chiefly to the development of the Boundary district, but the increased tonnage of the Rossland and Nelson districts has also had its effect. Approximately this gold has been derived from—

Direct smelting of copper-gold ores........	$3,474,738
Combined amalgamation and concentration..	873,865
Total........................	$4,348,603

It may be said that no absolutely 'free-milling' gold property is worked in the province; they all carry sufficient values in sulphides to necessitate the saving of such."

The following tables show the production of the Rossland mines and illustrate the average results attained during the past eight years.

NET PRODUCTION, PER SMELTER RETURNS.

Year.	Ore, tons, 2,000 lbs.	Gold, oz.	Silver, oz.	Copper, lbs.	Value.
1894....	1,856	3,723	5,357	106,229	$ 75,510
1895....	19,693	31,497	46,702	840,420	702,459
1896......	38,075	55,275	89,285	1,580,635	1,243,360
1897.............	68,804	97,024	110,068	1,819,586	2,097,280
1898......	111,282	87,343	170,804	5,232,011	2,470,811
1899.............	172,665	102,976	185,818	5,693,889	3,229,086
1900........	217,636	111,625	167,378	2,071,865	2,739,300
1901............	283,360	132,333	970,460	8,333,446	4,621,299
Total........	913,371	621,796	1,745,872	25,678,081	17,179,105

PRECIOUS METALS.

Gold.

British Columbia.

AVERAGE NET SMELTER RETURNS, OR ACTUAL YIELD PER TON.

Year.	Gold.	Silver.	Copper.	Value.
	Ounces.	Ounces.	%	$ cts.
1894	2·00	2·89	2·85	40 69
1895	1·60	2·41	2·10	35 67
1896	1·45	2·34	2·08	32 65
1897	1 42	1·60	1·32	30 48
1898	·78	1·54	2·35	22 10
1899	·596	1·07	1·65	18 70
1900	·513	769	·476	12 58
1901	·467	3·424	1·470	16 31
Average 913,371 tons	·681	1·911	1·405	18 81

Silver.

SILVER.

Production.

The production of silver in Canada in 1901 amounted to 5,539,192 ounces, valued at $3,265,354 or 58.95 cents per ounce, the average market value of the metal for the year in New York. The increase of the year's output as compared with 1900 was 1,070,967 ounces, though still less than the output of 1897 by 19,254 ounces.

Statistics of production of silver are shown in Table 12.

TABLE 12.

PRECIOUS METALS.

SILVER :—ANNUAL PRODUCTION.

Calendar Year.	Ontario.		Quebec.		British Columbia.		Total.	
	Ounces.	Value.	Ounces.	Value.	Ounces.	Value.	Ounces.	Value.
1887	190,495	$186,304	146,898	$143,666	17,690	$17,301	355,083	$347,271
1888	208,064	195,580	149,388	140,425	79,780	74,993	437,232	410,998
1889	181,609	169,986	148,517	139,012	53,192	49,787	383,318	358,785
1890	158,715	166,016	171,545	179,436	70,427	73,666	400,687	419,118
1891	225,633	222,926	185,584	183,357	3,306	3,266	414,523	409,549
1892	41,581	36,425	191,910	168,113	77,160	67,592	310,651	272,130
1893	....	8,689	....	126,439	....	195,000	....	330,128
1894	....	....	101,318	63,830	746,379	470,219	847,697	534,049
1895	....	....	81,753	53,369	1,496,522	976,930	1,578,275	1,030,299
1896	....	....	70,000	46,942	3,135,343	2,102,561	3,205,343	2,149,503
1897	5,000	2,990	80,475	48,116	5,472,971	3,272,289	5,558,446	3,323,395
1898	85,000	49,521	74,932	43,655	4,292,401	2,500,753	4,452,333	2,593,929

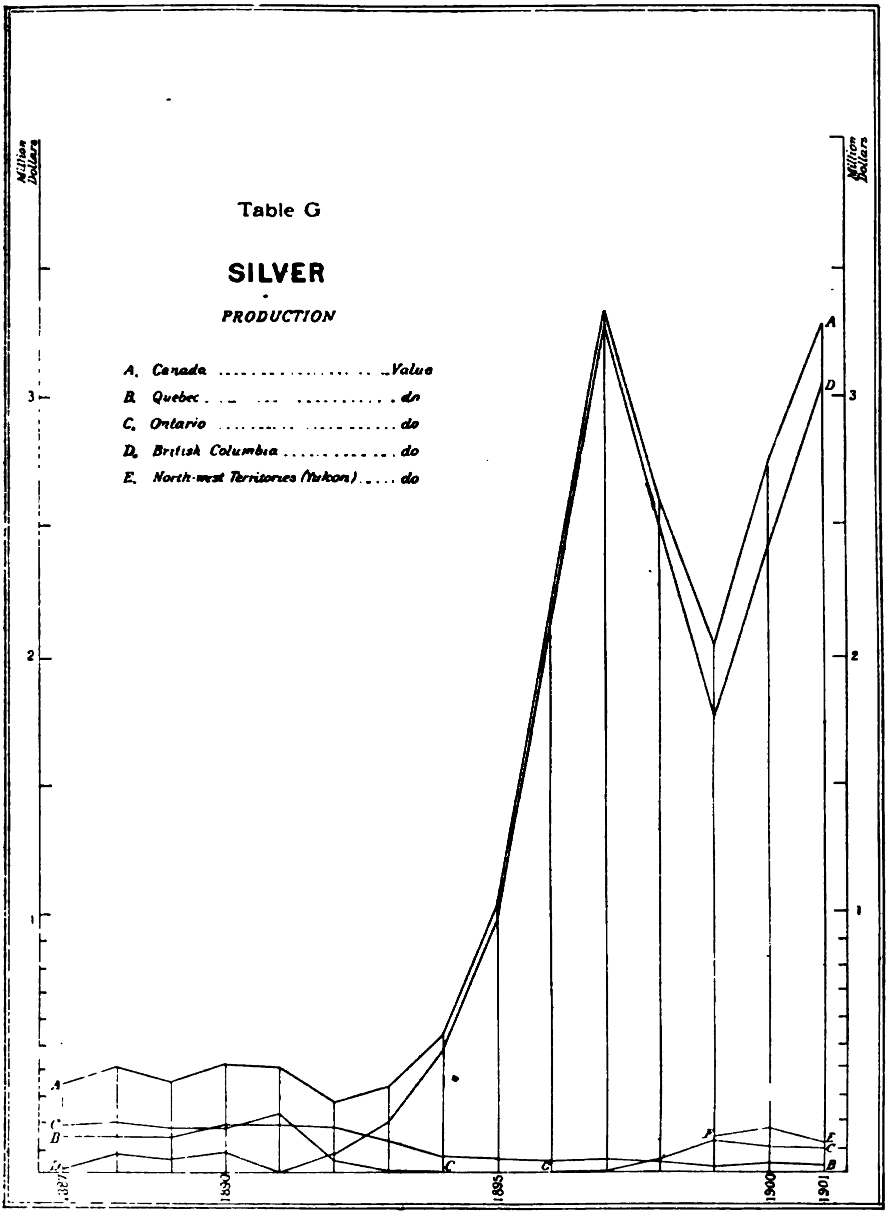

Table G

SILVER

PRODUCTION

PRECIOUS METALS.

Silver.

Production.

PROVINCE.	1899.		1900.		1901.	
	Ounces.	Value.	Ounces.	Value.	Ounces.	Value.
Quebec	40,231	$23,970	58,400	$35,817	41,459	$24,440
Ontario	202,000	120,352	161,650	99,140	151,400	89,250
Yukon district	230,000	137,034	290,000	177,857	195,000	114,953
British Col'mbia	2,939,413	1,751,302	3,958,175	2,427,548	5,151,333	3,036,711
	3,411,644	2,032,658	4,468,225	2,740,362	5,539,192	3,265,354

The silver produced in the province of Quebec, is represented by the small amount contained in the pyrites ores mined in the vicinity of Capelton in the "Eastern Townships". The pyrites is extracted primarily as a source of sulphur for acid making, but the silver is saved as a by-product.

The principal source of silver produced in Ontario since 1887 has been the West End Silver Mountain Mine, situated south-west of Port Arthur, in the Thunder Bay district.

The output of silver credited to the Yukon district during the past three years represents the silver carried by the placer gold obtained in this district.

British Columbia has since 1894 supplied the greater part of the silver production in Canada, the proportion of the total in 1901 being nearly 93 per cent.

The output by district for the past three years has been as follows :—

District.	1899.	1900.	1901.
	Ounces.	Ounces.	Ounces.
Cassiar	....	....	82
Kootenay East—			
Fort Steele division	33,516	960,411	718,451
Other divisions	1,627	2,219	34,181
Kootenay West—			
Ainsworth division	268,165	352,167	324,913
Nelson "	483,659	109,870	377,167
Slocan "	1,891,025	2,121,176	2,276,259
Trail Creek "	185,818	167,378	970,460
Other divisions	48,463	96,416	133,774
Yale			
Osoyoos division	2,719	112,145	241,489
Similkameen	16	....	
Yale	47	....	74
Coast and other districts	24,358	36,393	74,483
Totals	2,939,413	3,958,175	5,151,333

PRECIOUS METALS.

Silver.

Production.

There was a falling off in the output of silver-lead ores in 1901 with a consequent diminution in the production of silver in several of the districts producing silver-lead ores. This however has been more than made up by the increased output of silver from the Trail Creek, Boundary and Coast districts, etc., chiefly from copper-silver and gold-copper-silver ores. The total silver output from Trail Creek mines in 1901, was over five times what it was in 1900. There was of course a considerable increase in tonnage of ore handled, but there was also a very remarkable increase in the silver contents of the ores; while in 1900 the Trail creek ores smelted averaged only .769 of an ounce of silver to the ton, the output of 1901 averaged 3.424 ounces per ton.

The following tables show the output and average yield per ton of the Slocan mines for the past seven years.

NET PRODUCTION PER SMELTER RETURNS.

Year.	Ore, Tons, 2,000 lbs.	Silver oz.	Lead, lbs.	Gold. oz.	Values.
1895............. ...	9,514	1,122,770	9,666,324	6	$1,045,600
1896.................	16,560	1,954,258	18,175,074	152	1,854,011
1897....	33,567	3,641,287	30,707,705	193	3,280,686
1898...........	30,691	3,068,648	27,063,595	60	2,619,852
1899................	21,507	1,891,025	16,660,910	14	1,740,372
1900................	25,520	2,121,176	19,365,743	5.	2,063,908
1901.................	25,493	2,276,259	15,025,759	244	1,865,752
Total	162,852	16,075,423	136,665,110	674	14,470,181

AVERAGE YIELD PER TON.

Year.	Silver.	Lead.	Values.
1895...........	118·0 oz.	50·8%	$109 90
1896.................	118·0 "	54·9%	111 95
1897.................	108·5 "	45·7%	97 73
1898.................	100·0 "	44·1%	85 36
1899	87·9 "	38·7%	80 92
1900.................	83·1 "	37 9%	80 87
1901.............. .	89·3 "	29·5%	73 19
Average for seven y'rs, 162,852 tons..	98·7 oz.	41·9%	$88 85

PRECIOUS METALS.

Silver.

Exports of ore.

The value of silver ores exported is given in Table 13 following.

TABLE 13.

PRECIOUS METALS.

SILVER—EXPORTS OF ORE.

Calendar Year.	Value.	Calendar Year.	Value.
	$		
1886	25,957	1894	359,731
1887	206,284	1895	994,354
1888	219,008	1896	2,271,959
1889	212,163	1897	3,576,391
1890	204,142	1898	2,902,277
1891	225,312	1899	1,623,905
1892	56,688	1900	2,341,872
1893	213,695	1901	2,026,727

PYRITES.

PYRITES.

Production.

The output of pyrites, statistics of which are shown in the accompanying table, is almost altogether the product of the mines of the Eustis Mining Company, and the Nichols Chemical Co., situated in the Eastern Townships, province of Quebec. During the past two years however, there has been a small output of iron pyrites from the vicinity of Bannockburn, Ont.

TABLE 1.

PYRITES.

ANNUAL PRODUCTION.

Calendar Year.	Tons. 2,000 lbs.	Value.
		$
1886	42,906	193,077
1887	38,043	171,194
1888	63,479	285,656
1889	72,225	307,292
1890	49,227	123,067
1891	67,731	203,193
1892	59,770	179,310
1893	58,542	175,626
1894	40,527	121,581
1895	34,198	102,594
1896	33,715	101,155
1897	38,910	116,730
1898	32,218	128,872
1899	27,687	110,748
1900	40,031	155,164
1901	35,261	130,544

PYRITES.

Imports

TABLE 2.

PYRITES.

IMPORTS.—BRIMSTONE AND CRUDE SULPHUR.

Fiscal Year.	Pounds.	Value.
1880	1,775,489	$27,401
1881	2,118,720	33,956
1882	2 375,821	40,329
1883	2,336,085	36,737
1884	2,195,735	37,463
1885	2,248,986	35,043
1886	2,922,043	43,651
1887	3,103,644	38,750
1888	2,048,812	25,318
1889	2,427,510	34,006
1890	4,440,799	44,276
1891	3,601,748	46,351
1892	4,769,759	67,095
1893	6,381,203	77,216
1894	5,845,463	61,558
1895	4,900,225	56,965
1896	6,934,190	63,973
1897	8,672,751	87,719
1898	38,026,798	373,786
1899	24,517,026	265,799
1900	21,128,656	215,433
1901*	23,856,651	270,608

*Brimstone, crude, or in roll or flour, and sulphur in roll or flour. Duty free.

SALT.

SALT.

Production.

The production of salt in Canada in 1901, according to returns received, was 59,428 tons valued at $262,328, a slight falling off from the production of the previous year. The above figure represents the value of the salt alone, the value of the packages used, barrels, bags, etc., was over $85,000. This salt is altogether the product of wells in the counties of Essex, Lambton, Middlesex, Huron, and Bruce in the province of Ontario.

Small quantities of brine are occasionally evaporated at Plumweseep, N.B., and at Lake Winnipegosis, Man., but nothing has been done at either of these places during the past two years.

SALT.
Production.

TABLE 1.

SALT.

ANNUAL PRODUCTION.

Calendar Year.	Tons.	Value.
1886	62,359	$227,195
1887	60,173	166,394
1888	59,070	185,460
1889	32,832	129,547
1890	43,754	198,857
1891	45,021	161,179
1892	45,486	162,041
1893	62,324	195,926
1894	57,199	170,687
1895	52,376	160,455
1896	43,960	169,693
1897	51,348	225,730
1898	57,142	248,639
1899	59,339	254,390
1900	62,055	279,458
1901	59,428	262,328

Exports.

TABLE 2.

SALT.

EXPORTS.

Calendar Year.	Bushels.	Value.
1880	467,641	$46,211
1881	343,208	44,627
1882	181,758	18,350
1883	199,733	19,492
1884	167,029	15,291
1885	246,794	18,756
1886	224,943	16,886
1887	154,045	11,526
1888	15,251	3,987
1889	8,557	2,390
1890	6,605	1,667
1891	5,290	1,277
1892	2,000	504
1893	4,940	1,267
1894	4,639	1,120
1895	4,865	959
1896	3,842	899
1897	5,383	1,193
1898	5,202	1,252
1899	11,205	2,773
1900	37,653	8,997
1901	39,224	6,510

TABLE 3.

SALT.

IMPORTS—SALT PAYING DUTY.

Fiscal Year.	Pounds.	Value.	Fiscal Year.	Pounds.	Value.
1880	726,640	$ 3,916	1891	15,140,827	$59,311
1881	2,588,465	6,355	1892	18,648,191	65,963
1882	3,679,415	12,318	1893	21,377,339	79,838
1883	12,136,968	36,223	1894	15,867,825	53,336
1884	12,770,950	38,949	1895	8,498,404	29,881
1885	10,397,761	31,726	1896	7,665,257	24,550
1886	12,266,021	39,181	1897	11,911,766	33,470
1887	10,413,258	35,670	1898	11,068,785	32,792
1888	10,509,799	32,136	1899	11,781,453	32,839
1889	11,190,088	38,968	1900	11,028,337	30,180
1890	15,135,109	57,549			

		Duty.		
1901	Salt, coarse, N.E.S	5c. per 100 lbs.	7,298,504	20,494
	Salt, fine, in bulk	5c. "	2,391,400	5,185
	Salt, N.E.S., in bags, barrels or other packages	7½c. "	1,935,784	8,408
	Total		11,625,688	34,087

TABLE 4.

SALT.

IMPORTS—SALT NOT PAYING DUTY.

Fiscal Year.	Pounds.	Value.
1880	212,714,747	$400,167
1881	231,640,610	488,278
1882	166,183,962	311,489
1883	246,747,113	386,144
1884	225,390,121	321,243
1885	171,571,209	255,719
1886	180,205,949	255,359
1887	203,042,332	285,455
1888	184,166,986	220,975
1889	180,847,800	253,009
1890	158,490,075	252,291
1891	195,491,410	321,239
1892	201,831,217	314,995
1893	191,595,530	281,462
1894	196,668,730	328,300
1895	201,691,248	332,711
1896	205,005,100	338,888
1897	215,844,484	312,117
1898	202,634,927	293,410
1899	183,046,365	267,520
1900	193,554,550	295,253
1901*	216,271,603	339,887

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* Salt imported from the United Kingdom, or any British possession, or imported for the use of the sea or gulf fisheries.

STRUCTURAL MATERIALS.

STRUCTURAL MATERIALS.

Under this heading are comprised building stone, granites, marbles, slates, flagstone, cements, lime, &c., as well as the manufactures of clay, which include building bricks, tiles, drain-pipe, earthenware and coarse pottery.

The industries based on the structural materials are so widespread and are carried on in so many different places, on various scales and often intermittently, that it is impossible to obtain anything like complete returns of quantity or value of products. The figures of production are therefore to be taken only as rough approximations.

TABLE 1.

STRUCTURAL MATERIALS.

ANNUAL PRODUCTION OF BUILDING STONE.

Production of building stone.

Calendar Year.	Value.	Calendar Year.	Value.
1886	$ 642,509	1894	1,200,000
1887	552,267	1895	1,095,000
1888	641,712	1896	1,000,000
1889	913,691	1897	1,000,000
1890	964,783	1898	1,300,000
1891	708,736	1899	1,500,000
1892	609,827	1900	1,520,000
1893	1,100,000	1901	1,650,000

TABLE 2.

STRUCTURAL MATERIALS.

EXPORTS OF STONE AND MARBLE, WROUGHT AND UNWROUGHT.

Exports of stone and marble.

Calendar Year.	Wrought.	Unwrought.
1890	$21,725	$43,611
1891	13,398	46,162
1892	7,698	47,424
1893	9,102	12,532
1894	22,576	34,130
1895	8,587	51,616
1896	4,934	32,897
1897	9,415	42,034
1898	2,526	65,370
1899	5,092	101,931
1900	5,933	115,711
1901	5,917	157,739

Structural Materials.

Imports.

Building stone.

TABLE 3.

STRUCTURAL MATERIALS.

IMPORTS OF BUILDING STONE.

Calendar Year	Value.	Calenda Year.	Value.
1880	$ 35,970	1891	$170,890
1881	58,149	1892	95,550
1882	33,623	1893	56,510
1883	35,061	1894	52,908
1884	51,088	1895	44,282
1885	30,491	1896	54,130
1886	41,675	1897	38,714
1887	54,368	1898	28,495
1888	86,373	1899	48,040
1889	100,314	1900	64,533
1890	132,155		

1901	Flagstones, granite and rough freestone, sandstone, and all building stone, not hammered or chiselled. Duty 15 p.c.	$45,039
	Granite and freestones, dressed; all other building stone dressed, except marble. Duty 20 p.c.	1,039
		$46,078

Manufactures of stone or granite.

TABLE 4.

STRUCTURAL MATERIALS.

IMPORTS OF MANUFACTURES OF STONE OR GRANITE, N.E.S.

Fiscal Year.	Value.	Fiscal Year.	Value.
1880	$29,408	1891	$61,051
1881	36,877	1892	39,479
1882	37,267	1893	49,323
1883	45,636	1894	49,510
1884	45,290	1895	51,050
1885	39,867	1896	51,499
1886	41,984	1897	34,026
1887	41,829	1898	41,240
1888	47,487	1899	60,148
1889	61,341	1900	57,039
1890	84,396		

1901	Granite—Sawn only	Duty, 20 p.c.	$ 796
	" Finished and polished	" 35 p.c.	20,530
	" Manufactures of N.O.P	" 35 p.c.	21,220
	Paving blocks	" 20 p.c.	8,053
	Manufactures of stone, N.O.P	" 30 p.c.	16,040
			$66,639

STRUCTURAL MATERIALS.

Production of marble.

TABLE 5.

STRUCTURAL MATERIALS.

ANNUAL PRODUCTION OF MARBLE.

Calendar Year.	Tons.	Value.
1886	501	$9,900
1887	242	6,224
1888	191	3,100
1889	83	980
1890	780	10,776
1891	240	1,752
1892	340	3,600
1893	590	5,100
1894	Nil.	Nil.
1895	200	2,000
1896	224	2,405
1897 to 1901 inclusive	Nil.	Nil.

Imports of marble.

TABLE 6.

STRUCTURAL MATERIALS.

IMPORTS OF MARBLE.

Fiscal Year.			Value.
1880			$ 63,015
1881			85,977
1882			109,505
1883			128,520
1884			108,771
1885			102,835
1886			117,752
1887			104,250
1888			94,681
1889			118,421
1890			99,353
1891			107,661
1892			106,268
1893			96,177
1894			94,657
1895			83,422
1896			90,065
1897			77,150
1898			95,894
1899			101,879
1900			94,017
1901	Marble and manufactures of :—	Duty.	
	Marble sawn only	20 %	$69,000
	Finished and polished	35 %	9,242
	Rough, not hammered or chiselled	15 %	4,491
	Manufactures of, N.O.P.	35 %	13,426
	Total, marble and manufactures of		$96,159

STRUCTURAL MATERIALS.

Production.

Granite.

TABLE 7.

STRUCTURAL MATERIALS.

ANNUAL PRODUCTION OF GRANITE.

Calendar Year.	Tons.	Value.
1886	6,062	$63,309
1887	21,217	142,506
1888	21,352	147,305
1889	10,197	79,624
1890	13,307	65,985
1891	13,637	70,056
1892	24,302	89,326
1893	22,521	94,393
1894	16,392	109,936
1895	19,238	84,838
1896	18,717	106,709
1897	10,345	61,934
1898	23,897	81,073
1899	13,418	90,542
1900	....	80,000
1901	....	155,000

Slate.

TABLE 8.

STRUCTURAL MATERIALS.

ANNUAL PRODUCTION OF SLATE.

Calendar Year.	Tons.	Value.
1886	5,345	$64,675
1887	7,357	89,000
1888	5,314	90,689
1889	6,935	119,160
1890	6,368	100,250
1891	5,000	65,000
1892	5,180	69,070
1893	7,112	90,825
1894	....	75,550
1895	....	58,900
1896	....	53,370
1897	....	42,800
1898	....	40,791
1899	....	33,406
1900	....	12,100
1901	715	9,980

STRUCTURAL MATERIALS.

Slate.

Exports.

TABLE 9.

STRUCTURAL MATERIALS.

EXPORTS OF SLATE.

Calendar Year.	Tons.	Value.
1884	539	$6,845
1885	346	5,274
1886	34	495
1887	27	373
1888	22	475
1889	26	3,303
1890	12	153
1891	15	195
1892	87	2,038
1893	178	3,168
1894	187	3,610
1895	36	574
1896	301	8,913
1897	Nil.	Nil.
1898	Nil.	Nil.
1899	Nil.	Nil.
1900	Nil.	Nil.
1901	16,750	10,000

Imports.

TABLE 10.

STRUCTURAL MATERIALS.

IMPORTS OF SLATE.

Fiscal Year.	Value.	Fiscal Year.	Value.
1880	$21,431	1891	$46,104
1881	22,184	1892	50,441
1882	24,543	1893	51,179
1883	24,968	1894	29,267
1884	28,816	1895	19,471
1885	28,169	1896	24,176
1886	27,852	1897	21,615
1887	27,845	1898	24,907
1888	23,151	1899	33,100
1889	41,370	1900	53,707
1890	22,871		

		Duty.	
1901	Slate and manufactures of—		
	Mantels	30 %	$ 162
	Roofing slate	25% not over 75c per square	38,009
	School writing slates	25 %	17,548
	Slate pencils	25 %	4,384
	Slate of all kinds and manufactures of, N.E.S.	30 %	12,084
	Total		$72,187

STRUCTURAL MATERIALS.

Flagstone.

Production.

TABLE 11.

STRUCTURAL MATERIALS.

ANNUAL PRODUCTION OF FLAGSTONE.

Calendar Year.	Quantity, Sq. ft.	Value.
1886	70,000	$ 7,875
1887	116,000	11,600
1888	64,800	6,580
1889	14,000	1,400
1890	17,865	1,643
1891	27,300	2,721
1892	13,700	1,869
1893	40,500	3,487
1894	152,700	5,298
1895	80,005	6,687
1896	....	6,710
1897	....	7,190
1898	....	4,250
1899	....	7,600
1900	....	5,250
1901	....	4,575

Imports.

TABLE 12.

STRUCTURAL MATERIALS.

IMPORTS OF FLAGSTONE.

Fiscal Year.	Tons.	Value.
1881	23	$ 241
1882	90	848
1883	10	99
1884	137	1,158
1885	205	1,756
1886	1,602	9,443
1887	1,316	10,966
1888	2,642	21,077
1889	1,669	15,451
1890	5,665	48,995
1891	3,770	36,348
1892	1,571	15,048
1893	884	8,500
1894	218	2,429
1895	15	84
1896	Nil.	Nil.
1897	13	227
1898	587	1,540
1899	Nil.	Nil.
1900	9	63
*1901	14	116

* Flagstones dressed. Duty, 20 %. (See table 3).

STRUCTURAL MATERIALS.

Cement.

Cement :—Statistics of the production, exports and imports of cement are given in the six tables following.

The figures given in Table 13 represent the total sales and shipments of cement in each year. The sales in 1901 amounted to 450,394 barrels, as compared with 417,552 barrels in 1900, and 396,753 barrels in 1899. The total value of cement sold in 1901 was slightly less than in 1900, owing to the reduced prices prevailing during the past year. A reference to Table 17 will show that the imports of Portland cement have also been increasing rapidly during the past few years, the value of the imports in 1901 being about equal to the home production, so that only about half the demand is supplied by the Canadian product.

There were four firms in Ontario and one in Manitoba making natural rock cement, and the total quantity manufactured during the year was 148,628 barrels, while the sales were 133,328 barrels, and stocks on hand at December 31, 1901, 15,300 barrels.

Portland cement was manufactured by one firm in Quebec province and three in Ontario, and the total quantity made during the year was 360,160 barrels. The quantity sold was 317,066 barrels, and 58,094 barrels were in manufacturers' hands on December 31, 1901.

Following is a list of companies either operating or erecting plants for the manufacture of cement:—

Natural rock cement—

The Hamilton Cement Works	Hamilton, Ont.
The Queenston Cement Works	Queenston, Ont.
Battle's Thorold Cement Works	Thorold, Ont.
The Toronto Lime Company	Toronto, Ont.
The Manitoba Union Mining Co., Ltd.	Winnipeg, Man.

Portland cement—

The Crescent Cement Works	Longue Point, Que.
The Canadian Portland Cement Co.	Deseronto, Ont.
The Lakefield Portland Cement Co.	Lakefield, Ont.
The Imperial Cement Co., Ltd.	Owen Sound, Ont.
The Owen Sound Portl'd Cement Co., Ltd.	" "
The Sun Portland Cement Co., Ltd.	" "
The National Portland Cement Co., Ltd.	Toronto, Ont.
The Hanover Portland Cement Co	Hanover, Ont.

STRUCTURAL MATERIALS.

Cement.

Production.

TABLE 13.

STRUCTURAL MATERIALS.

ANNUAL PRODUCTION OF CEMENT.

Calendar Year.				Barrels.	Value.
1887				69,843	$ 81,909
1888				50,668	35,593
1889				90,474	69,790
1890				102,216	92,405
1891				93,473	108,561
1892				117,408	147,663
1893				158,597	194,015
1894				108,142	144,637
1895				128,294	173,675
1896				149,090	201,651
		Barrels.	Value.		
1897	Naturel	85,450	$ 65,893	205,213	$275,273
	Portland	119,763	209,380		
1898	Naturel	87,125	73,412	250,209	397,580
	Portland	163,084	324,168		
1899	Naturel	141,387	119,308	396,753	633,291
	Portland	255,366	513,983		
1900	Naturel	125,428	99,994	417,552	662,910
	Portland	292,124	562,916		
1901	Natural	133,328	94,415	450,394	660,030
	Portland	317,066	565,615		

Exports.

TABLE 14.

STRUCTURAL MATERIALS.

EXPORTS OF CEMENT.

Calendar Year.	Value.
1891	$ 2,881
1892	938
1893	1,172
1894	482
1895	937
1896	1,328
1897	644
1898	2,117
1899	2,733
1900	3,296
1901	1,514

STRUCTURAL MATERIALS.

Cement.

Imports.

TABLE 15.

STRUCTURAL MATERIALS.

IMPORTS ON CEMENT IN BULK OR BAGS.

Fiscal Year.	Bushels.	Value.	Fiscal Year.	Bushels.	Value.
1880	65	$ 28	1891	11,281	2,890
1881	579	298	1892	14,351	3,394
1882	386	86	1893	12,534	2,909
1883	1,759	548	1894	9,027	2,618
1884	4,626	1,236	1895	....	2,112
1885	4,598	1,315	1896	....	3,672
1886	6,808	1,851	1897	....	4,318
1887	5,421	1,419	1898	....	3,263
1888	23,919	5,787	1899	....	8,929
1889	32,818	10,668	1900	....	10,452
1890	21,055	5,443	1901*	....	4,890

*Cement, N.E.S., Duty 20 per cent.

TABLE 16.

STRUCTURAL MATERIALS.

IMPORTS OF HYDRAULIC CEMENT.

Fiscal Year.	Barrels.	Value.
1880	10,034	$ 10,306
1881	7,812	7,821
1882	11,945	13,410
1883	11,659	13,755
1884	8,606	9,514
1885	5,613	5,396
1886	6,164	6,028
1887	6,160	8,784
1888	5,636	7,522
1889	5,835	7,467
1890	5,440	9,048
1891	3,515	6,152
1892	2,214	2,782
1893	4,896	8,060
1894	1,054	985
1895	5,333	7,001
1896	5,688	8,948
1897	2,494	3,937
	Cwt.	
1898	16,033	7,097
1899	1,678	694
1900	10,418	4,711
1901 (Cement hydraulic or waterlime)*	17,784	6,865

*Duty, 12½c. per 100 lbs.

TABLE 17.

STRUCTURAL MATERIALS.

IMPORTS OF PORTLAND CEMENT.

Fiscal Year.	Barrels.	Value.
1880		$ 55,774
1881		45,646
1882		66,579
1883		102,537
1884		102,857
1885		111,521
1886		120,398
1887	102,750	148,054
1888	122,402	177,158
1889	122,273	179,406
1890	192,322	313,572
1891	183,728	304,648
1892	187,233	281,553
1893	229,492	316,179
1894	224,150	280,841
1895	196,281	242,813
1896	204.407	242,409
1897	210,871	252,587
	Cwt.	
1898	1,073,058	355,264
1899	1,300,424	467,994
1900	1,301,361	498,607
1901 (Portland)*	1.612,432	654,595

* Duty, 12½c. per 100 lbs.

TABLE 18.

STRUCTURAL MATERIALS.

PRODUCTION OF ROOFING CEMENT.

Calendar Year.	Tons.	Value.
1890	1,171	$ 6,502
1891	1,020	4,810
1892	800	12,000
1893	951	5,441
1894	815	3,978
1895	....	3,153
1896	86	430
1897 to 1901 inclusive	Nil.	Nil.

STRUCTURAL MATERIALS.

Lime.

Production.

TABLE 19.

STRUCTURAL MATERIALS.

ANNUAL PRODUCTION OF LIME.

Calendar Year.	Value.
1886	$283,755
1887	394,859
1888	339,951
1889	362,848
1890	412,308
1891	251,215
1892	411,270
1893 estimated	900,000
1894 "	900,000
1895 "	700,000
1896 "	650,000
1897 "	650,000
1898 "	650,000
1899 "	800,000
1900 "	800,000
1901 "	920,000

Exports.

TABLE 20.

STRUCTURAL MATERIALS.

EXPORTS OF LIME.

Calendar Year.	Value.
1891	$119,853
1892	121,535
1893	86,623
1894	83,670
1895	71,697
1896	70,820
1897	53,177
1898	49,594
1899	73,565
1900	80,852
1901	99,194

TRUCTURAL
ATERIALS.

ime.

mports.

TABLE 21.

STRUCTURAL MATERIALS.

IMPORTS OF LIME.

Fiscal Year.	Barrels.	Value.
1880	6,100	$ 6,013
1881	5,796	4,177
1882	5,064	5,365
1883	7,623	9,224
1884	10,804	11,200
1885	12,072	11,503
1886	11,021	9,347
1887	10,835	8,524
1888	10,142	7,537
1889	13,079	9,363
1890	8,149	5,360
1891	6,259	4,273
1892	6,132	4,241
1893	6,879	4,917
1894	6,766	4,907
1895	12,008	5,743
1896	10,239	7,331
1897	16,108	10,529
1898	12,850	9,002
1899	15,720	11,124
1900	12,865	11,211
1901 ... ... Duty, 20 p.c.	19,657	14,534

uilding
ricks.

roduction.

TABLE 22.

STRUCTURAL MATERIALS.

ANNUAL PRODUCTION OF BUILDING BRICKS.

Calendar Year.	Value.
1886	$ 873,600
1887	986,689
1888	1,036,746
1889	1,273,884
1890	1,266,982
1891	1,061,536
1892	1,251,934
1893	1,800,000
1894	1,800,000
1895	1,670,000
1896	1,600,000
1897	1,600,000
1898	1,900,000
1899	2,195,000
1900	2,275,000
1901	2,400,000

STRUCTURAL MATERIALS.

Bricks.

Exports.

TABLE 23.

STRUCTURAL MATERIALS.

EXPORTS OF BRICKS.

Calendar Year.	M.	Value.
1891	246	$1,163
1892	1,963	12,192
1893	6,073	44,110
1894	1,095	7,405
1895	1,655	8,665
1896	983	5,678
1897	573	2,679
1898	65	442
1899	172	1,351
1900	546	4,528
1901	646	5,189

Imports.

TABLE 24.

STRUCTURAL MATERIALS.

IMPORTS OF BUILDING BRICK.

Fiscal Year.	Value.
1880	$ 2,067
1881	4,281
1882	24,572
1883	14,234
1884	20,258
1885	14,632
1886	5,929
1887	2,440
1888	20,720
1889	24,585
1890	12,500
1891	9,744
1892	5,075
1893	14,108
1894	18,320
1895	4,705
1896	23,189
1897	10,336
1898	6,652
1899	21,306
1900	19,305
1901 Duty, 20 p.c.	20,677

Imports of paving brick in 1898: Value, $2,337; duty, 20 p.c.
" " 1899: " 23,648; "
" " 1900: " 35,644; "
" " 1901: " 10,414; "

STRUCTURAL MATERIALS.

Terra cotta.

Production.

TABLE 25.

STRUCTURAL MATERIALS.

PRODUCTION OF TERRA COTTA, &c.

Calendar Year.	Value.
1888	$ 49,800
1889	Not available.
1890	90,000
1891	113,103
1892	97,239
1893	55,704
1894	65,600
1895	195,123
1896	83,855
1897	155.595
1898	167,902
1899	220,258
1900	259,450
1901	278,671

Sewer pipes.

TABLE 26.

STRUCTURAL MATERIALS.

PRODUCTION OF SEWER PIPES, &c.

Calendar Year.	Value.
1888	$266,320
1889	Not available.
1890	348,000
1891	227,300
1892	367,660
1893	350,000
1894	250,325
1895	257,045
1896	153,875
1897	164,250
1898	181,717
1899	161,546
1900	231,525
1901	248,115

STRUCTURAL MATERIALS.

Drain tiles and sewer pipes.

Imports.

TABLE 27.
STRUCTURAL MATERIALS.
IMPORTS OF DRAIN TILES AND SEWER PIPES.

Fiscal Year.	Value.
1880	$ 33,796
1881	37,368
1882	70,065
1883	70,699
1884	71,755
1885	69,589
1886	57,953
1887	71,203
1888	101,257
1889	83,215
1890	77,434
1891	87,195
1892	59,537
1893	39,001
1894	24,625
1895	21,053
1896	19,296
1897	34,286
1898	29,611
1899	33,898
1900	39,149

		Duty.	
1901	Drain tile, not glazed	20 %	$ 1,264
	Drain pipes, sewer pipes, chimney linings or vents, chimney tops and inverted blocks, glazed or unglazed	35 %	54,819
	Total		$56,083

Pottery.

Production.

TABLE 28,
STRUCTURAL MATERIALS.
ANNUAL PRODUCTION OF POTTERY.

Calendar Year.	Value.
1888	$ 27,750
1889	Not available
1890	195,242
1891	258,844
1892	265,811
1893	213,186
1894	162,144
1895	151,588
1896	163,427
1897	129,629
1898	214,675
1899	185,000
1900	200,000
1901	200,000

STRUCTURAL MATERIALS.

Earthenware.

Imports.

TABLE 29.

STRUCTURAL MATERIALS.

IMPORTS OF EARTHENWARE.

Fiscal Year.	Value.	Fiscal Year.	Value.
1880	$322,333	1891	$634,907
1881	439,029	1892	748,810
1882	646,734	1893	709,737
1883	657,886	1894	695,514
1884	544,586	1895	547,935
1885	511,853	1896	575,493
1886	599,269	1897	595,822
1887	750,691	1898	675,874
1888	697,082	1899	916,727
1889	697,949	1900	959,526
1890	695,206		

		Duty.	
1901	Earthenware and china :—		
	Baths, tubs and washstands, of earthenware, stone cement or clay, or of other material, N.O.P.	30 %	$ 22,620
	Brown or coloured earthen and stoneware, and Rockingham ware	30 %	19,328
	Decorated, printed or sponged, and all earthenware, N.E.S	30 %	291,843
	Demijohns, churns and crocks	30 %	972
	White granite or ironstone ware, C.C. or cream coloured ware	30 %	193,726
	China and porcelain ware	30 %	331,007
	Earthenware tiles	35 %	34,413
	Manufactures of earthenware, N.E.S.	30 %	220,768
	Total		1,114,677

Sand and gravel.

Exports.

TABLE 30.

STRUCTURAL MATERIALS.

EXPORTS OF SAND AND GRAVEL.

Calendar Year.	Tons.	Value.
		$
1893	329,116	121,795
1894	324,656	86,940
1895	277,162	118,359
1896	224,769	80,110
1897	152,963	76,729
1898	165,954	90,498
1899	242,450	101,640
1900	197,558	101,666
1901	197,302	117,465

MISCELLANEOUS.

MISCELLANEOUS.

Antimony:—There has been no record of production of antimony ore since 1898. In that year there was a resumption of work for a short time at the Rawdon mines, Hants county, Nova Scotia, which mines had been idle since 1891, when they were closed down owing to the reduced price of antimony. Previous to that year they were worked more or less actively from the time they were opened up in 1884. Antimony.

Table 2 shows that some antimony has been exported from Canada under the name of antimony ore, although the mines recorded no production. This discrepancy is thought to arise from a misapplication of the term antimony ore. The exports probably represent some manufacture of antimony produced from imported material.

Other deposits of antimony ore are known to occur in Canada, some of which have been worked to a small extent. Mention of these has been made in previous reports of the Section.

TABLE 1.

MISCELLANEOUS.

ANNUAL PRODUCTION OF ANTIMONY ORE.

Production.

Calendar Year.	Tons.	Value.
1886	665	$31,490
1887	584	10,860
1888	345	3,696
1889	55	1,100
1890	26½	625
1891	10	60
1892 to 1897	Nil.	Nil.
1898	1,344	20,000

MISCELLANEOUS.

Antimony.

Exports.

TABLE 2.

MISCELLANEOUS.

EXPORTS OF ANTIMONY ORES.

Calendar Year.	Tons.	Value.	Calendar Year.	Tons.	Value.
1880.........	40	$ 1,948	1889.........	30	$ 695
1881.........	34	3,308	1890.........	38	1,000
1882.........	323	11,673	1891.........	3½	60
1883.........	165	4,200	1892 to 1897..	Nil.	Nil.
1884.........	483	17,875	1898.........	1,232	15,296
1885.........	758	36,250	1899........	6¾	190
1886.........	665	31,490	1900.........	210	3,441
1887..... .	229	9,720	1901.........	10	1,643
1888.........	352½	6,894			

Imports.

TABLE 3.

MISCELLANEOUS.

IMPORTS OF ANTIMONY.

Fiscal Year.	Pounds.	Value.	Fiscal Year.	Pounds.	Value.
1880.........	42,247	$ 5,903	1891.........	114,084	17,483
1881..... ..	....	7,060	1892..	180,308	17,680
1882.........	183,597	15,044	1893...	181,823	14,771
1883.........	105,346	10,355	1894.........	139,571	12,249
1884...	445,600	15,564	1895.........	79,707	6,131
1885..	82,012	8,182	1896.........	163,209	9,557
1886..	89,787	6,951	1897.........	134,661	8,031
1887..	87,827	7,122	1898.........	156,451	12,350
1888.........	120,125	12,242	1899.........	289,066	16,851
1889.........	119,034	11,206	1900...... ..	186,997	20,001
1890........	117,066	17,439			

		Duty.		
1901	Antimony, or regulus of, not ground pulverized or otherwise manufactured.	Free.	195,626	$ 7,799
	Antimony salts........	"	155,111	16,915
	Total....	.. ..	350,737	24,714

Arsenic.

Arsenic.—The production of arsenic in 1901 was 695 tons, valued at $41,676. This is over twice the quantity produced in 1900 and more than twelve times that produced in 1899.

It is all obtained as a by-product in working the auriferous mispickel ores of the Deloro mine, Hastings county, Ont., and this is the only mine on the continent producing arsenic at the present time. The world's supply of arsenic is derived largely from England and

MISCELLANEOUS.

Arsenic.

Germany, the production for the past six or seven years having varied from 7,000 to 8,000 metric tons per annum.

The greater part of the Canadian product finds a market in the United States, the imports into which country in 1900 of white and metallic arsenic and arsenic sulphides amounted to 5,765,559 lbs. valued at $265,500.

TABLE 4.

MISCELLANEOUS.

ANNUAL PRODUCTION OF ARSENIC.

Production.

Calendar Year.	Tons.	Value.
1885	440	$17,600
1886	120	5,460
1887	30	1,200
1888	30	1,200
1889	Nil.	Nil.
1890	25	1,500
1891	20	1,000
1892	Nil.	Nil.
1893	"	"
1894	7	420
1895	Nil.	Nil.
1896	"	"
1897	"	"
1898	"	"
1899	57	4,872
1900	303	22,725
1901	695	41,676

TABLE 5.

MISCELLANEOUS.

IMPORTS OF ARSENIC.

Imports.

Fiscal Year.	Pounds.	Value.	Fiscal Year.	Pounds.	Value.
1880	18,197	$ 576	1891	115,248	4,027
1881	31,417	1,070	1892	302,958	9,365
1882	138,920	3,962	1893	447,079	12,907
1883	51,953	1,812	1894	292,505	10,018
1884	19,337	773	1895	1,115,697	31,932
1885	49,080	1,566	1896	664,854	27,523
1886	30,181	961	1897	152,275	8,378
1887	32,436	1,116	1898	291,967	14,270
1888	27,510	1,016	1899	582,383	24,203
1889	69,269	2,434	1900	230,730	11,035
1890	138,509	4,474	1901...Duty free.	159,263	8,361

MISCELLANEOUS.

Chalk and whiting.

Imports.

Chalk and Whiting.—The needs of Canada in respect to these two articles are entirely met by importation. The total value of the imports of these two products amount to over $70,000, so that a home market awaits the finder of deposits having the necessary qualities to meet the needs of users of the imported articles.

TABLE 6.

MISCELLANEOUS.

IMPORTS OF CHALK.

Fiscal Year.	Value.	Fiscal Year.	Value.
1880..	$2,117	1891..	8,193
1881......	2,768	1892...........	9,558
1882...........	2,882	1893...........	9,966
1883..	5,067	1894...........	11,308
1884...........	2,589	1895...........	7,730
1885...........	8,003	1896...........	6,467
1886....	6,583	1897..........	7,432
1887..	5,635	1898...........	9,338
1888...........	5,865	1899..	10,461
1889.......... .	5,336	1900..	12,212
1890...........	7,221	1901*..........	11,629

* Chalk prepared Duty, 20 p. c.

TABLE 7.

MISCELLANEOUS.

IMPORTS OF WHITING.

Fiscal Year.	Cwt.	Value.
1880................	84,115	$26,092
1881	47,480	16,637
1882	36,270	16,318
1883	76,012	29,334
1884................	76,268	28,230
1885	67,441	23,492
1886	65,124	25,533
1887...........	47,246	15,191
1888.......... . ..	76,619	20,508
1889.......	84,658	22,735
1890	96,243	27,471
1891.	84,679	27,504
1892....	102,985	26,867
1893................	88,835	25,563
1894..	103,633	26,649
1895................	102,751	25,441
1896	113,791	27,822
1897................	102,453	22,541
1898.	166,293	25,761
1899................	134,884	34,310
1900....	127,455	34,575
1901*.........	209,868	60,878

*Whiting or whitening, gilders whiting, and Paris white. Duty free.

MISCELLANEOUS.

Feldspar.

Feldspar.—The production of feldspar in Canada in 1901 was 5,350 tons, valued at $14,548 at Montreal. A few hundred tons were sold from Mr. W. A. Allan's mine, township of Templeton, Ottawa county, Quebec, but the greater part of the output was mined by the Kingston Feldspar Mining Company from their property in Bedford township, Frontenac county, Ontario.

TABLE 8.

MISCELLANEOUS.

PRODUCTION OF FELDSPAR.

Production.

Calendar Year.	Tons.	Value.
1890	700	$3,500
1891	685	3,425
1892	175	525
1893	575	4,525
1894	Nil.	Nil.
1895	....	*2,545
1896	972	*2,583
1897	1,400	3,290
1898	2,500	6,250
1899	3,000	6,000
1900	318	1,112
1901	5,350	14,548

* Exports.

Fire-clay.

Fire-clay.— Returns of fire-clay production were received from British Columbia, Nova Scotia and New Brunswick, the importance of the value from each province being in the order named. Practically the total output is obtained in connection with the mining of coal from thin beds usually underlying the coal seams, and the material is mostly used locally in the construction and repairs of coke ovens and in connection with metallurgical operations.

In connection with refractory materials, it might be interesting to mention that experiments were made on samples from a deposit of felsite near Coxheath Hills, Cape Breton, N.S. This series of experiments conducted in the laboratory of the Geological Survey of Canada some years ago has shown the material to be well adapted to the manufacture of fire bricks.

Miscellaneous.

Fire-clay.

Production.

TABLE 9.

MISCELLANEOUS.

PRODUCTION OF FIRE-CLAY.

Calendar Year.	Tons.	Value.
1889	400	$4,800
1890	Nil.	Nil.
1891	250	750
1892	1,991	4,467
1893	540	700
1894	539	2,167
1895	1,329	3,492
1896	842	1,805
1897	2,118	5,759
1898	670	1,680
1899	599	1,295
1900	1,245	4,130
1901	3,979	5,920

Mercury.

Mercury.—There has been no output of mercury since 1897. The small output for the years 1895, 1896 and 1897 was obtained from the cinnabar mines in the vicinity of Kamloops lake, B.C.

These deposits are the only known occurrences of mercury ore in Canada which appear to be of economic value, but the mines have in reality never been worked beyond preliminary development, nor have the reduction works built near them passed the experimental stage. The main deposits in Lower Kamloops lake district are those of Cooper creek, and of Hardie mountain which are situated at a distance of about three miles from each other. The country rock consists of a Tertiary eruptive, very basic in character which is traversed by felspathic zones containing veins of quartz, calcite and dolomite with cinnabar, which in some places occurs in very rich pockets. Descriptions of the deposits and of work done in the district, as well as of the plants erected, will be found in the reports of the Minister of Mines for British Columbia for the past few years, as well as in reports of this Section.

'The properties owned by the Hardie Mountain Cinnabar Company, have been the subject of negotiations which it is hoped will lead to the speedy resumption of work on a large scale. On the other claims on Hardie mountain the necessary assessments have been performed, and on the "Toon-Kwa" situated 12 miles south of Savonas, the work done shows a good body of cinnabar ore.'*

---

* Rep. Minister of Mines for B.C. 1901 p. 1020.

MISCELLANEOUS.

Mercury.

Production.

TABLE 10.

MERCURY.

PRODUCTION.

Calendar Year.	Flask (76½ lbs.)	Price per flask.	Value.
1895........................	71	$ 33 00	$ 2,343
1896........................	58	33 44	1,940
1897........................	9	36 00	324

Imports.

TABLE 11.

MERCURY.

IMPORTS.

Fiscal Year.	Pounds.	Value.
1882.	2,443	$ 965
1883..................	7,410	2,991
1884..................	5,848	2,441
1885..................	14,490	4,781
1886..................	13,316	7,142
1887..................	18,409	10,618
1888..................	27,951	14,943
1889..................	22,931	11,844
1890..................	15,912	7,677
1891..................	29,775	20,223
1892..................	30,936	15,038
1893..................	50,711	22,998
1894..................	36,914	14,483
1895..................	63,732	25,703
1896..................	77,869	32,343
1897..................	76,058	33,534
1898..................	59,759	36,425
1899..................	103,017	51,695
1900..................	85,342	51,987
1901.........Duty free	140,610	- 94.564

Moulding sand.

Moulding Sand :—The figures given in Table 12 are derived from returns of railway shipments and do not therefore nearly represent the total production. Deposits of sands answering the requirements of moulding sand are known to occur in almost every province, and in many cases are worked for the local wants. Of those it is almost impossible to keep record or to obtain returns of output from the producers. The greater proportion of the above railway shipments is derived from deposits in the Ontario peninsula, and is exported to the United States.

MISCELLANEOUS.

Moulding sand.

Production.

TABLE 12.
MISCELLANEOUS.
PRODUCTION OF MOULDING SAND.

Calendar Year.	Tons.	Value.
1887	160	$ 800
1888	169	845
1889	170	850
1890	320	1,410
1891	230	1,000
1892	345	1,380
1893	4,370	9,086
1894	6,214	12,428
1895	6,765	13,530
1896	5,739	11,478
1897	5,485	10,931
1898	10,572	21,038
1899	13,724	27,430
1900	6,181	12,316
1901	14,705	29,410

Quartz.

Quartz :—No returns of production of quartz have been received for the past two years. Quartz mining in Canada is irregular and spasmodic and is not the object of a definite industry. The small quantities which have been mined at different times were used mostly as refractory material entering the composition of furnace linings.

There are numerous other uses to which quartz may be put.

In the United States, the production of quartz represents a substantial figure. The output of quartz of that country is mainly derived from the mining of vein quartz and is used chiefly for the manufacture of certain potteries.

Production.

TABLE 13.
MISCELLANEOUS.
ANNUAL PRODUCTION OF QUARTZ.

Calendar Year.	Tons.	Value.
1890	200	$ 1,000
1891	....	....
1892	....	....
1893	100	500
1894	....	....
1895	....	....
1896	10	50
1897	....	....
1898	284	570
1899	600	1,260
1900	....	....
1901	....	....

MISCELLANEOUS.

Quartz.

Imports.

TABLE 14.

MISCELLANEOUS.

IMPORTS OF "SILEX"—CRYSTALLIZED QUARTZ.

Fiscal Year.	Cwt.	Value.
1880	5,252	$ 2,290
1881	3.251	1,659
1882	3,283	1,678
1883	3,543	2,058
1884	3,259	1,709
1885	3,527	1,443
1886	2,520	1,313
1887	14,533	5,073
1888	4,808	2,385
1889	5,130	1,211
1890	1,768	2,617
1891	3,674	1,929
1892	1,429	1,244
1893	2,447	1,301
1894	2,451	1,521
1895	2,882	1,881
1896	3,289	2,174
1897	2,564	3,415
1898	3,104	2,773
1899	3,951	2,595
1900	4,021	2,876
1901 .... Duty free.	3,662	2,106

Soapstone.

Soapstone :—As may be seen from the following table, soapstone is another material of which the production is irregular. No output has been reported for the year 1901, but it is not due to absence of deposits. A list of steatite deposits of workable size was given in the report of this Section for 1897.

TABLE 15.

MISCELLANEOUS.

ANNUAL PRODUCTION OF SOAPSTONE.

Production.

Calendar Year.	Tons.	Value.	Calendar Year.	Tons.	Value.
1886	50	$ 400	1894	916	1,640
1887	100	800	1895	475	2,138
1888	140	280	1896	410	1,230
1889	195	1,170	1897	157	350
1890	917	1,239	1898	405	1,000
1891	Nil	Nil	1899	450	1,960
1892	1,374	6,240	1900	420	1,365
1893	717	1,920	1901		

Tin.

Tin :—No ores of tin are known to occur in Canada, and the various reports of finds of tin ore have never been substantiated; there is therefore no production to record.

MISCELLANEOUS.

The importance of Canadian trade in tin and tin manufactures may be gathered from the accompanying table.

TABLE 16.

MISCELLANEOUS.

IMPORTS OF TIN AND TINWARE.

Tin and tinware.

Imports.

Fiscal Year.	Value.	Fiscal Year.	Value.
1880	$ 281,880	1891	$1,206,918
1881	413,924	1892	1,594,205
1882	790,285	1893	1,242,994
1883	1,274,150	1894	1,310,389
1884	1,018,493	1895	973,397
1885	1,060,883	1896	1,237,684
1886	1,117,368	1897	1,274,108
1887	1,187,312	1898	1,550,851
1888	1,164,273	1899	1,372,813
1889	1,243,794	1900	2,418,455
1890	1,289,756		

		Duty.	
1901	Tin crystals	Free.	$ 2,410
	Tin in blocks, pigs and bars	"	697,664
	Tin plates and sheets	"	1,466,965
	Tin foil	"	49,758
	Tin strip waste	"	110
	Tin and manufactures of: –		
	Tin plate in sheets, decorated	25 %	329
	Tinware, plain, japanned, or lithographed and all manufactures of tin, N.E.S.	25 %	121,873
	Total		$2,339,109

Tripolite.

Tripolite:—No returns were received direct from operators of tripolite deposits, but Dr. E. Gilpin, Inspector of Mines for Nova Scotia estimates the production for the fiscal year 1901 at 800 tons. This product is put to various uses such as polishing material, steam pipe covering, etc. The following are the chief known deposits in Canada.

Quebec Province, Montcalm county, Chertsey Tp., range V, lot 15.

New Brunswick, Fitzgerald lake, Pollet River lake.

Nova Scotia, Colchester county, Bass river; Victoria county, St. Ann; Cumberland county, Folly lake; besides numerous minor occurrences.

MISCELLANEOUS.

Tripolite.

Production.

TABLE 17.
MISCELLANEOUS.
PRODUCTION OF TRIPOLITE.

Calendar Year.	Tons.	Value.
		$
1896	664	9,960
1897	15	150
1898	1,017	16,660
1899	1,000	15,000
1900	336	1,950
1901	....	....

Zinc.

Zinc :—The only operators were the Grand Calumet Mining Company, who operate the Zenith mine near Nipigon bay, Lake Superior. Operations at the Calumet island mines which had been a producer for three or four years, have been discontinued.

The production of zinc for the past four years stands as follows: 1898, tons 394, value $36,011; 1899, tons 407, value $46,805; 1900, tons 106, value $9,342.

Although the Ontario Mining Bureau reports some production from the Zenith mine nothing has been credited to the year 1901 herein, as from returns received directly from the company, no ore was sold or shipped or otherwise utilized. As frequently explained on former occasions "production" for purposes of this report is always limited to mineral substances realized upon in some way in distinction from that merely mined, quarried, etc., and stored in dumps to be utilized or not, as may happen in future years.

Imports.

TABLE 18.
MISCELLANEOUS.
IMPORTS OF ZINC IN BLOCKS, PIGS AND SHEETS.

Fiscal Year.	Cwt.	Value.	Fiscal Year.	Cwt.	Value.
1880	13,805	$67,881	1891	17,984	$105,023
1881	20,920	94,015	1892	21,881	127,302
1882	15,021	76,631	1893	26,446	124,360
1883	22,765	94,799	1894	20,774	90,680
1884	18,945	77,373	1895	15,061	63,373
1885	20,954	70,598	1896	20,223	80,784
1886	23,146	85,599	1897	11,946	57,754
1887	26,142	98,557	1898	35,148	112,785
1888	16,407	65,827	1899	18,785	107,477
1889	19,782	83,935	1900	28,748	156,167
1890	18,236	92,530	1901 Duty free	20,527	103,457

MISCELLANEOUS.

Imports.

Spelter.

TABLE 19.

MISCELLANEOUS.

IMPORTS OF SPELTER.

Fiscal Year.	Cwt.	Value.
1880	1,073	$ 5,310
1881	2,904	12,276
1882	1,654	7,779
1883	1,274	5,196
1884	2,239	10,417
1885	3,325	10,875
1886	5,432	18,238
1887	6,908	25,007
1888	7,772	29,762
1889	8,750	37,403
1890	14,570	71,122
1891	6,249	31,459
1892	13,909	62,550
1893	10,721	49,822
1894	8,423	35,615
1895	9,249	30,245
1896	10,897	40,548
1897	8,342	32,826
1898	2,794	13,561
1899	5,450	29,687
1900	5,836	29,416
1901*.......Duty free.	14,621	58,283

*Spelter in blocks and pigs.

TABLE 20.

MISCELLANEOUS.

Manufactures of zinc.

IMPORTS OF ZINC, MANUFACTURES OF.

Fiscal Year.	Value.	Fiscal Year.	Value.
1880	$ 8,327	1891	$7,178
1881	20,178	1892	7,563
1882	15,526	1893	7,464
1883	22,599	1894	6,193
1884	11,952	1895	5,581
1885	9,459	1896	6,290
1886	7,345	1897	5,145
1887	6,561	1898	10,503
1888	7,402	1899	14,661
1889	7,233	1900	11,475
1890	6,472		

		Duty.	
1901	Zinc seamless drawn tubing	Free.	$ .....
	" manufactures of, N.O.P	25 %	6,882
	Total		6,882

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